FINAL TECHNICAL REPORT – USGS COOPERATIVE AGREEMENT FOR UCB BOREHOLE SEISMIC NETWORK

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Title:	UCB Borehole Network: Northern Hayward Fault network (NHFN), High Resolution Seismic network (HRSN-Parkfield)		
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Project Web Site:	NHFN: http://www.ncedc.org/bdsn/hfn.overview.html http://www.ncedc.org/bdsn/mpbo.overview.html HRSN: http://www.ncedc.org/hrsn/ http://www.ncedc.org/hrsn/hrsn.archive.html		

ABSTRACT

The UCB borehole network project is composed of two local networks that provide 3-component borehole coverage in the north and east Bay-Area (19-station, NHFN) and in the Parkfield region of California (13-station, HRSN). The networks have now been fully integrated into California real-time seismic monitoring through the NCSS processing stream and play dual roles by contributing to response applications and the collection of basic data for long-term hazards mitigation and by complementing surface networks with coverage of high-gain, high-sample-rate (up-to 500 sps) low-noise borehole recordings of very low amplitude seismic signals for fundamental research on earthquake and fault-zone related problems. Though the role of the borehole networks for response applications and basic data collection is an important one, the special properties of the borehole data make the networks additionally valuable though their unique ability to contribute to cutting edge research on earthquakes, non-volcanic tremor, deep fault-zone drilling (e.g. SAFOD), and other fault zone related properties. Considerable effort has been made during this cooperative agreement period to maintain optimal performance and expand the networks to allow them to continue to fulfill their dual roles in earthquake response and collection of basic and research grade data.

INTRODUCTION

The UCB borehole network project is composed of two local networks that provide 3-component borehole coverage in the north and east Bay-Area (19-station, NHFN, Figure 1a) and in the Parkfield region of California (13-station, HRSN, Figure 1b). The networks are now fully integrated into California real-time seismic monitoring through the NCSS processing stream and play dual roles by both contributing to response applications and the collection of basic data for long-term hazards mitigation and by complementing surface networks with coverage of high-gain, high-sample-rate (up-to 500 sps) low-noise borehole recordings of very low amplitude seismic signals for fundamental research on earthquake related problems. Below we first provide background for each of the networks and then follow with yearly network summaries of accomplishments, activities and operational status (2007, p. 4-15; 2008, p. 16-31; 2009-10, p. 32-48).

Background NHFN

Operation of this Bay Area borehole network is funded by both the ANSS and through the Berkeley Seismological Laboratory's partnership with the California Department of Transportation (Caltrans). ANSS provides operations and maintenance (O&M) support for a fixed subset of 9 stations that were initiated as part of previous projects in which the USGS was a participant. Caltrans provides O&M support for an additional 10 stations that have been or are in the process of being added to the network with Caltrans partnership grants. Caltrans also continues to provide additional support for upgrade and expansion of the network. Figure 1a shows the locations of NHFN network stations and provides links to the networks station list. Yearly summaries of activities and accomplishments (presented below) will be given for the entire NHFN entity (i.e., the combined USGS and Caltrans supported stations).

Background HRSN

Operation of the borehole HRSN (Figure 1b) is funded entirely by the USGS through this cooperative agreement. However, resources are heavily leveraged through cooperative efforts with the USGS in the Parkfield area to keep O&M costs to a minimum. The HRSN occupies an important geographic location at the transition zone between the creeping San Andreas Fault (SAF) to the northwest and the fully locked Cholame segment of the SAF to the SE. Rupture of the Cholame segment on its own is believed capable of producing an ~7Mw earthquake and the segment is believed to have contained the starting point of the great 7.8Mw Fort Tejon earthquake of 1857. The previous rupture of this segment took place as part of the 1857 event, and the segment's average recurrence time of 140 years suggests considerable risk of its participation in a large earthquake in the near future (WGCEP, 2005).

The San Andreas Fault Observatory at Depth (SAFOD) experiment is also centrally located within the HRSN and the high-frequency, broadband (~0.5-100Hz) borehole coverage of the HRSN provides a critical complement to the experimental data being collected by SAFOD. In particular, HRSN data is being used to provide azimuthal coverage and high-sample-rate, high signal to noise recordings of ongoing microseismic activity in the immediate SAFOD target zone that are being used for high-precision relocations of both repeats of the SAFOD M2 target events and associated smaller events to magnitudes below 0.0Mw. These smaller events are not only important for defining the seismic structure of the SAFOD target zone, but also for more advanced studies using the small events as eGf's for imaging the slip distribution of the target M2's, for repeating earthquake studies, for studies of earthquake scaling (to magnitudes approaching laboratory scale) and for imaging changes in fault-zone scattering properties associated with strain and stress transients.

At the northwest end of the Cholame segment, deep (15 to 30 km) non-volcanic tremor (NVT) activity was also recently discovered with HRSN borehole data, and the low-noise, high-gain borehole HRSN recordings of this activity are playing a vital role in this active area of fault zone research. Furthermore, recent developments in the use of ambient seismic noise correlation using continuous low-noise records from the HRSN have shown that monitoring for changes in deep fault zone properties in this important area (e.g., deformation, seismic velocity and state of stress) may be viable.

Given these factors, we have put considerable effort into maintaining optimal performance of the HRSN to allow it to fulfill its dual roles for earthquake response and the collection of basic and research grade data.

ACCOMPLISHMENTS 2007

Northern Hayward Fault Network (NHFN):

Changes Implemented in 2007

The NHFN is one of two UCB borehole network projects and provides borehole coverage in the north and east Bay Area of California. It is primarily a research network that complements regional surface networks by providing down-hole recordings of very low amplitude seismic signals (e.g., from micro-earthquakes or non-volcanic tremor) at high gain and low noise. Many of the NHFN stations are also located coincident with or close to large structures such as Bay Area Bridges, and provide data on the earth's dynamic response to earthquakes at depths below typical seismic sensors, thus providing base level measurements for estimation of site amplification effects on the large structures.

In response to the review panels concerns that too much emphasis was placed on the research applications of the NHFN in our initial proposal, we have now integrated the data from the NHFN into California real-time seismic monitoring operations (i.e., through the NCSS processing stream) for response applications and collection of basic data for long-term hazards mitigation. Below we describe changes made to the NHFN entity in 2007 (i.e., changes relating to overall network operations and to both ANSS and Caltrans supported stations) since the start date of the cooperative agreement.

Integration into real-time earthquake processing and standard tool implementation. We have now completed the integration of data flow from all operating NHFN stations into the Northern California Seismic System (NCSS) real-time/automated processing stream. The NCSS is a joint USGS (Menlo Park) and Berkeley Seismological Laboratory (BSL) entity with earthquake reporting responsibility for Northern California, and data from networks operated by both institutions are processed jointly to fulfill this responsibility. Data from the NHFN stations now contribute to this effort and consequently have phase-picks generated which are subsequently used in the real-time processing of earthquake locations. Also as part of the NCSS processing, the NHFN picks, waveforms and the NCSS event locations and magnitudes are automatically entered into a database where they are immediately available to the public through the NCEDC and its DART (Data Available in Real Time) buffer. The capability for monitoring state of health information for all NHFN stations using *SeisNetWatch* has also now been added, and up-to-date datalesss SEED formatted metadata is now made available by the NCEDC with the *SeismiQuery* software tool.

New stations. We have now fully upgraded our only post-hole (3.4 meter deep) site (SMCB) with a deep borehole (150.9 meter) installation (SM2B) at St. Mary's College. An overlap period of ~ 60 days of coincident data from both stations was also collected and analyzed for calibration purposes, and the new site is on-line and contributing real-time data to the NCSS. This new site was added in partnership with St. Mary's college and Caltrans. Through our partnership with Caltrans significant progress on infrastructure installation has been made at 4 additional sites where deep boreholes have been drilled and instrumented (PETB, E07B, W05B and RB2B). These sites are expected to come on-line within the next few months. Permit negotiations continue for two additional sites (PINB and one at the Cal Maritime Academy), which through our partnership with Caltrans are to have velocity and accelerometer packages installed in deep boreholes.

Partnerships. The NHFN is heavily leveraged through partnerships with various institutions. We have continued to nurture and expand on these partnerships and in 2007 we obtained a long-term (3-year) operations and maintenance funding through Caltrans for the their complement of 10 of the 19 NHFN stations. In 2007 we also began work on establishing a 3-year partnership with Caltrans and the Lawrence Berkeley National Laboratory to expand the NHFN with 3 additional borehole installations and to upgrade several NHFN sites with strong-motion surface sensors to provide up-hole down-hole data for fundamental research on amplification effects in the upper ~1-200 meters. We have also renewed and extended our partnership with St. Mary's college on whose property our new deeper borehole installation (SM2B) resides. Finally, we are working with the Cal Maritime Academy, with the East Bay Parks district and the Plate Boundary Observatory to form partnerships that will allow us to install new borehole stations at various new locations.

High Resolution Seismic Network (HRSN):

Operation of the borehole HRSN is funded entirely through this cooperative agreement. Below we describe changes made to the HRSN 2007 since the start date of the agreement.

Integration into real-time earthquake processing and standard tool implementation. Through the BSL's partnership with the USGS in Menlo Park, a T1 line is now providing real-time telemetry of all data channels from the HRSN to Menlo Park and Berkeley, and is allowing direct internet communication with the individual HRSN stations for monitoring and remote trouble-shooting. The real-time data channels are now integrated with real-time data from the other networks operated by the BSL and USGS and processed by the NCSS system for real-time/automated earthquake determinations, reporting and cataloging.

The addition of the borehole HRSN data to the NCSS processing has significantly lowered the magnitude threshold in the Parkfield region and by so doing is contributing previously unavailable information on very low magnitude seismicity for the SAFOD (San Andreas Fault Observatory at Depth) project and for the general research community. The T1 line access to Berkeley is also now allowing for a continuous data feed into the NCEDC through which near-real-time monitoring of nonvolcanic tremor activity in the Parkfield-Cholame area is being attempted.

As part of the NCSS processing, the HRSN picks and waveforms are automatically entered into a database along with the NCSS determined event locations and magnitudes and are made immediately available to the public through the NCEDC and its DART (Data Available in Real Time) buffer. The capability for monitoring state of health information for all the HRSN stations using *SeisNetWatch* has also now been added, and up-to-date datalesss SEED formatted metadata for the HRSN channels is now made available through the NCEDC with the *SeismiQuery* software tool.

Major tasks.
At the time of our cooperative agreement proposal, the central site data acquisition computer had been experiencing intermittent failures and was in need of replacement. Fortunately we had requested in our proposal and received funding to replace the aged computer, which eventually did fail completely. We were able to re-route data flow in a stop-gap measure over the newly established T1 line to minimize data loss, and we have now purchased and installed the replacement computer at Parkfield. Software will be installed on the system (to be done remotely over the internet) next week after which data redundant storage capacity of several weeks will be restored.

Operational costs for the HRSN have been continuing to rise significantly, due primarily to somewhat exorbitant increases in landowner fees for our primary telemetry relay site at Gastro Peak (GP) (recently increased to $9800/yr., 1-year terms only). It was recommended by the review panel that we work to better integrate operations of the HRSN with USGS operations to help reduce costs. In 2007 and in close coordination with Dave Croker at the USGS Menlo Park, we plans, reached agreements and began field implementation of a major transfer of our GP based telemetry scheme with a telemetry scheme based at the USGS Hog Canyon (HOGS) site. We also made arrangements with Freddie Blume of UNAVCO to use one of their sites for additional telemetry relay paths if needed. Once the alternative telemetry scheme is operational, our intent is to request a significant reduction in fees at the GP site or if necessary not to renew our GP agreement next year (at the risk of losing one HRSN site that exists directly on GP). This should significantly reduce the per. site costs for HRSN operations since currently the GP fees represent over 9% of the entire HRSN budget.

Data Management Practices (NHFN and HRSN 2007)
Data from all NHFN and HRSN stations are telemetered in real-time to the Northern California Earthquake Data Center at UC Berkeley. Telemetry paths vary from station to station, but when things are working well, most data arrive within 5 s of their timestamp, and are immediately available for real-time processing (Standard 4.1). At the same time, they are made available to external users in the data center's DART (Data Available in Real Time) buffer (Standard 5.1). U.C. Berkeley Seismological Laboratory (BSL) staff are available to deal with telemetry problems 24/7, to ensure that real-time data collection is impeded as little as possible. If there

are gaps in the data center's collection, missing data are retrieved from the station when telemetry resumes.

As they arrive at the data center, data from the NHFN and HRSN stations are automatically fed into processing streams designed to pick phases (Standard 4.3). Phase picks are available shortly after the data's arrival, in general within 10 s. We have implemented RAD processing on the real-time system, to continuously produce picks, which we are exchanged with USGS Menlo Park. Automated amplitude information for the borehole networks is not currently provided in near-real-time and awaits a more robust methodology for scaling amplitudes from borehole sensors (that are of variable depths and whose high gain recordings can severely clip on near-by moderate and large earthquakes) for magnitude determinations (Standard 4.2).

The BSL and the USGS Menlo Park share earthquake reporting responsibility for Northern California through the Northern California Seismic System (NCSS). The NHFN and HRSN data streams come into the BSL in real-time and are contributed to the NCSS for event processing. Event times and locations from the NCSS are usually made public within 15 s of an earthquake detected by the combined networks (Standard 5.1). Parameters for events at or beyond the combined networks' edges may be somewhat delayed (30 s). Various magnitude types are determined with coda magnitudes (M_d) taking possibly as long as several minutes. For events of magnitude 3.0 and greater, local magnitude (M_L) is calculated within 30 s of M_d, and moment magnitude (M_w) within 5 minutes of the origin time (i.e., when applicable and possible). Event information is stored automatically in a database. Our earthquake processing system is currently in transition to the CISN software. As a result, catalog information for old events (before Nov 29, 2006) is stored in flat-files, while for new events it is stored in the database. The "Event bulletin" – the catalog that includes both current and historical data – is being updated hourly with recent information from the database. When the transition is complete, users will be able to retrieve the most up-to-date catalog information from the database at any time (Standard 5.2).

Metadata are current and publicly available via the *SeismiQuery* software (Standard 5.3). Metadata information for all NHFN and HRSN stations is maintained by the NCEDC where care is taken to update the metadata quickly when equipment has been changed. We also QC the metadata regularly using large teleseisms to confirm the expected response to ground motion is consistent across the network.

Data from the NHFN and HRSN stations is stored in the archives of the NCEDC (Standard 5.4). Real-time data becomes available there almost immediately. The real-time data are replaced with quality checked data (completeness, timing problems corrected), usually within 3-5 days of their production.

Continuity of Operations and Response Planning (NHFN and HRSN, 2007)
The BSL collects, processes and archives the NHFN and HRSN data. Consequently all the continuity and response planning efforts implemented by the BSL also apply to the NHFN and HRSN data flow. These include archival of the data in a "quake-safe" building, UPS, a generator with fuel for 4-7 days, master and slave data acquisition computers and real-time processing computers. In addition each NHFN station has 1-day of data storage capacity in case of telemetry failures. A central site data collection node also exists at Parkfield for the HRSN where several weeks' worth of local data storage capacity and emergency UPS and generator exists for coping with power and communication failures.

Progress on Metadata Development (NHFN and HRSN, 2007)
Current metadata information for all NHFN and HRSN stations (including response information) are maintained and available through the NCEDC where care is taken to update the metadata quickly when equipment has been changed. The metadata is publicly available over the web through the NCEDC via *SeismiQuery* software (http://www.ncedc.org/SeismiQuery) (Standard 5.3). Metadata information is also regularly quality checked using large teleseisms to confirm that the expected response to ground motion is consistent across all the NHFN, HRSN and the BSL's BDSN stations.

Data from the NHFN and HRSN stations is stored in the archives of the NCEDC (Standard 5.4). Real-time data becomes available there almost immediately. The real-time data are replaced with quality checked data (completeness, timing problems corrected), usually within 3-5 days of their production.

Table 1. Summary Statistics for Regional/Urban Seismic Network (to 30 Nov. 2007)
This table contains combined information for both the NHFN and HRSN for stations that are currently fully operational. Four additional borehole stations are instrumented and in their final stages of infrastructure installation.

Total no. of stations operated and/or recorded	**28**
Total no. of channels recorded	**110**
No. of short-period (SP) stations	**28**
No. of short-period (SP) stations with metadata	**28**
No. of broadband (BB) stations	**0**
No. of broadband (BB) stations with metadata	**0**
No. of strong-motion (SM) stations	**8**
No. of strong-motion (SM) stations with metadata	**8**
No. of stations maintained & operated by network	**28**
-same, with full metadata	**28**
No. of stations maintained & operated as part of ANSS	**22**
-same, with full metadata	**22**
Total data volume archived (mbytes/day)	**1870**

Table 2. Earthquake Data and Information Products (2007)

Network Products		
Does the network provide the following?	**Yes/No**	**Comments/Explanation**
Primary EQ Parameters		
Picks	Yes	Through NCSS
Hypocenters	Yes	Through NCSS
Magnitudes (& Amplitudes)	Yes	Through NCSS
Focal mechanisms	No	
Moment Tensor(s)	Yes	Through NCSS
Other EQ Parameters/Products		
ShakeMap	Yes	Through NCSS
Finite Fault	Yes	Through NCSS
Supplemental Information		
Felt Reports	Yes	We encourage people to submit to the CIIM website
Event Summary	Yes	Through NCSS
Tectonic Summary	No	
Collated Maps	No	
Refined Hypocenters (e.g. double-difference)	No	Currently developing procedures for automated cataloging (including double-difference relocations) of similar and repeating microearthquakes.
Web Content		
Recent EQ Maps	Yes	CISN – with USGS MP
Station Helicorder	No	
Station noise PDFs	Yes	
Station Performance Metrics	Yes	
Network Description	Yes	NCEDC website links
Station List	Yes	NCEDC website links

Network Products		
Does the network provide the following?	**Yes/No**	**Comments/Explanation**
Station Metadata	**Yes**	**NCEDC/SeismiQuery**
Email Notification Services	**Yes**	**For moment tensors primarily**
Contact Info	**Yes**	
Region-specific FAQs	**No**	
Region-specific EQ info	**Yes**	
Waveforms		
Triggered	**Yes**	
Continuous	**Yes**	
Processed	**Yes**	**We provide V0 data to the SMEC and the NSMEDC within 24 hours of an event**
Summary Products		
Catalogs	**Yes**	**From NCSS processing**
Metadata		
Instrument Response	**Yes**	
Site Info (e.g. surface geology, Vs30)	**No**	

Descriptions:

***Tectonic Summary*: Text and/or figures describing the tectonic setting of the event and related activity**

***Event Summary*: Text and/or figures (press releases, collated media/disaster agencies info) that describes the earthquake and its effects**

***Collated Maps*: Any map or set of maps that illustrates the event properties, tectonics, hazards, etc**

***Processed Waveforms*: Specialized processing that is required by some portion of the community, e.g. processed strong motion records for the engineering community**

***Catalogs*: Lists of parameters that describe an earthquake(s) or information used to describe an earthquake (e.g., picks, locations, amps,..)**

Network Products		
Does the network provide the following?	**Yes/No**	**Comments/Explanation**
***Region-specific earthquake information*: Description (text and/or maps) of historical earthquakes, faults/geology, etc.**		

Appendix A: ANSS Cooperating Network Performance Self-Rating

Question	Answer	Explanation (if needed)
1. What is the minimum magnitude detection threshold for your network?	< 0.8 M_d	We cooperate with the USGS Menlo Park to form the NCSS. Together, we detect and locate quakes with magnitudes below M_d 0.8
2. What is the minimum magnitude detection threshold for the best instrumented part of your network?	< 0.8 M_d	We cooperate with the USGS Menlo Park to form the NCSS. Together, we detect and locate quakes with magnitudes below M_d 0.8 (the lower limit of M_d)
3. What is the typical hypocentral location accuracy for earthquakes occurring within your network? Is it the same for automated vs. reviewed?	~ 500 m or less	yes
4. Does your network report automated earthquake locations into QDDS? If yes, how long does it take?	yes	It depends on the location. The initial report can be 15-30 s after the event.
5. Does your network report analyst-reviewed earthquake locations for all quakes into QDDS (i.e., the little ones)?	not yet	We await the CISN software to extend reporting. If yes, what is the typical processing delay?
7. Describe the velocity model used to locate earthquakes in your network (1-D?, multiple models?, 3-D?). Does it differ for automated vs. reviewed?	currently multiple models	no
8. What software/program does your network use to locate earthquakes? Does it differ for automated vs. reviewed?	hypo inverse	no.
9. What magnitudes does your network routinely report in real time (Md, ML, Me, Mw, Ms etc.)? How long does it take to compute them?	M_d, M_L, M_w	M_d depends on event size, up to 4 minutes M_L 30 s after M_d M_w 5 minutes after origin time
10. Does your network archive phase information at a datacenter?	yes	If yes, how long is the delay to report? immediate In what year does archiving begin? 2004 for HRSN; 2007 for NHFN Where is the information archived? NCEDC

Appendix A: ANSS Cooperating Network Performance Self-Rating

Question	Answer	Explanation (if needed)
11. Does your network archive summary (i.e., earthquake catalog) information at a public datacenter?	yes	If yes, how long is the delay to report? Immediate In what year does archiving begin? 2004 for HRSN; 2007 for NHFN
12. Does your network archive event waveforms at a public datacenter?	yes	If yes, describe what type of channels (e.g., EH, HH, HN) and how long is the delay to report? NHFN: DP,BP,LP,CL,BL,LL, EP HRSN: DP,BP Currently data is telemetered in real-time and is generally available for external users through the NCEDC's DART system within 5 to 10 sec. In what year does archiving begin?
13. Do you archive continuous waveforms at a public datacenter?	yes	If yes, describe which channels and how long is the delay to report? NHFN: BP,LP,BL,LL HRSN: DP,BP Delay 5-10 sec. In what year does archiving begin? NHFN: 1995 HRSN: 2001
14. If your network archives waveforms, does it supply supporting instrument response metadata to support generation waveforms in SEED? For all waveforms?	yes and yes	
15. Does your network compute focal mechanisms?	yes	Networks contribute to mechanisms through NCSS processing. If yes, what type (first motion, moment tensor). Moment Tensor. In real-time? Within ~5 minutes.

Appendix A: ANSS Cooperating Network Performance Self-Rating

Question	Answer	Explanation (if needed)
		Do you archive them at a public datacenter? yes
16. Does your network automatically distribute email to the public in near real-time for significant events?	no	If yes, Do you offer a website where they can sign up? We encourage them to go to ENS.
17. Does your network automatically distribute alphanumeric pages to the public in near real-time for significant events?	no	Not to the general public. Only to a select set of users. If yes, Do you offer a website where they can sign up? No. We encourage public to use
18. Does your network automatically compute *ShakeMaps* and make them publicly available? If so, how long does it take?	yes	Networks contribute to NCSS processing and subsequent ShakeMaps. Takes 5-10
19. Does your network operate a fault-tolerant system (e.g., redundant computers, UPS, back-up generator with lots of fuel)?	yes	In a "quake-safe" building, UPS, backup generator with fuel for 4-7 days, master and slave data acquisition computers and real-time processing computers.
20. What does your network do with the data recorded on ANSS strong motion instruments? For example, do you make it available to the engineering community through a Data Center?	yes	Strong motion data are stored in the NCEDC. V0 is prepared within 24 hours of a quake and sent to the National Strong Motion data center (Sacramento)

Additional Information, Comments and Suggestions (2007)

The NHFN and HRSN now contribute real-time data from 28 stations to California real-time seismic monitoring operations (i.e., through the NCSS processing stream) for response applications and collection of basic data for long-term hazards mitigation. In addition, these networks provide to the research community unique borehole recordings of very low amplitude seismic signals (e.g., from micro-earthquakes or non-volcanic tremor) at high gain and low noise. Data from the NHFN also provide down-hole accelerometer data that, in conjunction with surface strong motion recordings, provide important basic information on near surface amplification effects in the free-field and near critical structures in the heavily Urbanized Bay Area. Data from the HRSN also complements major research initiatives in the Parkfield-Cholame area of California (e.g. SAFOD (the San Andreas Fault Observatory at Depth) and PBO (Plate Boundary Observatory)) where intensive research on the recently discovered non-volcanic tremor phenomena and on the seismic and related properties of the deep San Andreas Fault zone are taking place.

Hence these networks are providing functionality for both real-time seismic monitoring applications and for cutting-edge research on fault zone and earthquake hazard related issues. We feel, therefore, that the cost of continued operation of these networks relative to the value of the data that they provide to the earthquake community is low.

ACCOMPLISHMENTS 2008

Northern Hayward Fault Network (NHFN):

Changes Implemented in 2008

Integration into real-time earthquake processing and standard tool implementation. By the end of the 2008 period we completed the integration of data flow from all operating NHFN stations into the Northern California Seismic System (NCSS) real-time/automated processing stream. The NCSS is a joint USGS (Menlo Park) and Berkeley Seismological Laboratory (BSL) entity with earthquake reporting responsibility for Northern California, and data from networks operated by both institutions are processed jointly to fulfill this responsibility. Data from the NHFN stations now contribute to this effort and consequently have phase-picks generated which are subsequently used in the real-time processing of earthquake locations. Also as part of the NCSS processing, the NHFN picks, waveforms and the NCSS event locations and magnitudes are automatically entered into a database where they are immediately available to the public through the NCEDC and its DART (Data Available in Real Time) buffer. The capability for monitoring state of health (SOH) information for all NHFN stations using *SeisNetWatch* has now been added as has automated monitoring and alarm notifications of problematic network performance by the REDI system. We are also in the process of implementing routine inspection of waveforms from significant and repeating earthquakes when they occur to identify problematic changes in real-earthquake response over time. Up-to-date datalesss SEED formatted metadata is also now available by the NCEDC with the *SeismiQuery* software tool.

New stations. In 2008 we completed the upgrade of our only post-hole (3.4 meter deep) site (SMCB) with a deep borehole (150.9 meter) installation (SM2B) at St. Mary's College. An overlap period of ~ 60 days of coincident data from both stations was also collected and analyzed for calibration purposes, and the new site is on-line and contributing real-time data to the NCSS. Over the past year, considerable field effort has been placed into hardening the site and knocking down spurious noise sources so that the data currently being recorded by SM2B is now on par with the quality of borehole data from other NHFN sites and of significantly better signal to noise than was available from the 3.4 meter post-hole installation. This new site was added in partnership with St. Mary's college and Caltrans.

Through our partnership with Caltrans significant progress on infrastructure installation has been made at 4 additional sites where deep boreholes have been drilled and instrumented (PETB, E07B, W05B and RB2B). These sites are expected to come on-line within the next year as contributed efforts from our Caltrans partner are completed and as retrofit projects on the Bay Bridge are completed.

With Caltrans funding, we have also purchased velocity and acceleration sensors and instrumentation for 2 additional sites, and Caltrans will provide drilling for these sites as spare drilling crew time becomes available (i.e., holes of opportunity).

Permit negotiations for one of these sites (PINB, shown in Figure 1a) are in their final stages, and permitting and siting for the other additional site at Cal Maritime Academy (north of the Carquinez strait across from station CRQB: Figure 1a) has been completed. Drilling and sensor installation at these two sites will take place as permitting is completed and Caltrans drill crews become available.

Network Adaptations. In August of 2007, recording of seismic signals from one of the NHFN backbone sites (BBEB) was necessarily terminated due to seismic retrofit work on the east span of the Bay Bridge. Unexpectedly, Caltrans contractors decided that the borehole site containing the permanently emplaced BBEB seismic package had to be destroyed in order to carry out retrofit objectives. The BBEB installation also served as a relay site for data telemetry from other borehole stations on the east and west spans of the bridge. Fortunately the portions of the BBEB installation critical for telemetry relay were recoverable, and we have now adapted to these necessities, by keeping BBEB as the principal relay site for NHFN stations located along the Bay Bridge and by continuing negotiations with Caltrans to replace the installation at a new near-by site and associated funding for new borehole cabling, sensor packages and drilling time.

Additional and Continuing Caltrans Funding Efforts. In FY2008, we submitted a competitive proposal to Caltrans to expand the NHFN with 3 additional borehole installations and to upgrade several NHFN sites with strong-motion surface sensors to provide up-hole down-hole data for fundamental research on amplification effects in the upper ~1-200 meters. Unfortunately, in spite of high hopes on the part of both Caltrans and ourselves, the proposal was not funded in this year's round. Nonetheless, we are continuing our discussions with our partners at Caltrans for a possible resubmittal of the proposal in the future.

The California budget crisis also jeopardized continued funding of our agreement with Caltrans for O&M of the Caltrans supported component of the NHFN. After considerable effort we were fortunately able to reinstate support for the O&M, and are hopeful that our efforts have established precedence to help isolated the O&M funding from future state budgetary problems.

Partnerships. The NHFN is heavily leveraged through partnerships with various institutions. We have continued to nurture and expand on these partnerships and since the start date of the cooperative agreement we have obtained long-term (3-year) operations and maintenance funding through Caltrans for the their complement of 10 of the 19 NHFN stations. We are also continuing our efforts at establishing a 3-year partnership with Caltrans and the Lawrence Berkeley National Laboratory to expand the NHFN with 3 additional borehole installations and to upgrade several NHFN sites with strong-motion surface sensors to provide up-hole down-hole data for fundamental research on amplification effects in the upper ~1-200 meters.

We have also renewed and extended our partnership with St. Mary's college through the recent installation of our new borehole installation (SM2B), made possible in large part by donated time from St Mary's grounds crew, and we have also recently completed siting and permitting agreements with the Cal Maritime Academy for a future installation on their property. Finally, we are continuing to work with the East Bay Parks district and the UNAVCO to form a partnership that will allow us to install a new borehole station (and collocated GPS) at Pt. Pinole and possibly at several other new locations. We also continue to work with Lawrence Berkeley National Laboratory, and non-ANSS components of the USGS, to either resurrect previously funded partnership activities or to establish entirely new partnerships focused on continued NHFN expansion.

High Resolution Seismic Network (HRSN):

Integration into real-time earthquake processing and standard tool implementation.
Through the BSL's partnership with the USGS in Menlo Park, a T1 line is now providing real-time telemetry of all data channels from the HRSN to Menlo Park and Berkeley, and is allowing direct internet communication with the individual HRSN stations for both automated and hands on remote monitoring of the network's state of health to increase efficiency of trouble-shooting efforts. The real-time data channels are now also fully integrated into the Northern California Seismic System (NCSS) real-time/automated processing stream. The NCSS is a joint USGS (Menlo Park) and Berkeley Seismological Laboratory (BSL) entity with earthquake reporting responsibility for Northern California, and data from networks operated by both institutions are processed jointly to fulfill this responsibility. Data from the HRSN stations now contribute to this effort and consequently have phase-picks generated which are subsequently used in the real-time processing of earthquake locations. Also as part of the NCSS processing, the HRSN picks, waveforms and the NCSS event locations and magnitudes are automatically entered into a database where they are immediately available to the public through the NCEDC and its DART (Data Available in Real Time) buffer. The capability for monitoring state of health (SOH) information for all HRSN stations using *SeisNetWatch* has now been added as has automated monitoring and alarm notifications of problematic network performance by the REDI system. Up-to-date datalesss SEED formatted metadata is also now available by the NCEDC with the *SeismiQuery* software tool. We are also in the process of implementing routine inspection of waveforms from significant and repeating earthquakes when they occur to identify problematic changes in real-earthquake response over time.

Major Telemetry Restructuring.
Several factors contribute to the relatively high per station high costs of the HRSN including: a) increasing land-owner fees related to increased demand for access to relatively few properties (primarily as a result of SAFOD activity), b) the remoteness of HRSN stations on the sparsely populated ranch land in this area (requiring 4-wheel vehicle costs and the packing in of equipment and on foot at several sites) and c) the need to maximize timing accuracy and minimize down-time and spurious

noise signals to provide robust research quality data which increasingly rely on full waveform, high precision data for differential measurements of temporal change in fault zone and recurrent earthquake properties. Furthermore, the few large ranches that occupy the majority of land in the area has led to an over dependence on the good-will or greed of just a few land-owners that can jeopardize long-term monitoring efforts should ownership of the properties change hands or should relationships with the land-owners go awry.

The review panel for this cooperative agreement recommended that in order to be more efficient with the USGS ANSS operational and maintenance dollars we should work with the USGS to reduce the high per station cost of the HRSN by better integrating the network financially and operationally with existing seismic monitoring structures in northern California. We also recognized that better integration with the USGS resources would also help reduce our land-owner fees and our over-dependence on land-owner relationships. In 2008 and in close coordination with Dave Croker at the USGS Menlo Park, we have now implementation of a major transfer of telemetry of 6 HRSN stations through our single Gastro Peak (GP) relay site with a diversified telemetry scheme based at the USGS Hog Canyon site (HOGS) for stations SCYB, CCRB and SMNB, at the USGS Middle Mountain site (PMM) for stations MMNB and VARB and at the USGS Carr Hill site for station GHIB. We have also dismantled the GP relay installation, providing future savings in land owner fees at the site of up to $9800/yr. Careful planning and coordination have kept equipment and labor costs for this effort low, and we were able to absorb these costs through a combination of the savings on land owner fees and through resources contributed by the Berkeley Seismological laboratory and the USGS.

Fortunately this restructuring was completed before the land-owner had decided not to renew our lease agreement at GP. Unfortunately, one of the borehole HRSN sites (RMNB) is permanently installed on GP, and is no longer under a land use agreement. At this time, the land-owner has allowed us to continue operation of RMNB (which also serves as a relay site for station LCCB) without cost. We recognize that this may be only a temporary arrangement and are continuing to explore alternatives for dealing with the RMNB (and LCCB relay) issue(s).

JCNB Outage. In the Spring of 2008, signals from HRSN station JCNB began showing signs of deterioration. Shortly thereafter, data flow from this station stopped completely. Field investigation showed that during installation in 1986-7, the borehole sensor and cable had been grouted to within ~100 feet of the surface and that a rodent had found itself trapped in the upper 100 foot void space and had chewed through the cable, thus severing the connection to the deep borehole package. At this time, costs for reestablishing connection to the cable at depth have been prohibitive, and it is also likely that the permanently emplaced sensor has been compromised by fluids running down the exposed cable. Current plans are being made to substitute either a surface seismometer or a borehole sensor package (possibly a Guralp) within the open 100 foot section of the borehole to provide continued seismic coverage at the JCNB site.

Central Site Acquisition Computer. At the time this cooperative agreement proposal was submitted, the central site data acquisition computer had been experiencing intermittent failures and was in need of replacement. As part of the proposal, we had requested and received support to replace the aged computer, which eventually failed completely in the spring of 2008. During the interim period before installation of the new computer, data flow was rerouted over the recently established USGS-BSL T1 line-telemetry and essentially no data was lost. Software installation and testing of the new computer was then performed remotely over the internet. Tests revealed that the manufacturer had provided a faulty disk, and this disk was then replaced. The replacement computer is now fully operational and has been processing the central site data flawlessly since May and has been providing backup support with redundant storage capacity of several weeks at times of telemetry (e.g., T1 line) failure.

Similar Event Catalog Software Development. We have now completed the software development and testing of our semi-automated similar event detection and cataloging scheme based on cross-correlation scans of continuous HRSN data. The method uses a small number of reference events whose waveforms, picks, locations, and magnitudes have been accurately determined, and it automatically detects, picks, locates, and determines magnitudes for events similar to the reference event to the level of relative accuracy and precision that only relative event analysis can bring.

We have applied the methodology using a test set of 25 reference events from diverse locations within the HRSN coverage and scanned these events through continuous seismic records from July 27, 2001 through Sept. 1, 2008 (spanning both the M6.5 San Simeon and M6 Parkfield earthquakes). Scanning of the reference events yielded 1296 unique similar event detections that were then processed using highly automated procedures to yield high-precision picks, routine and relative event relocations, and precise magnitude estimates (using low frequency spectra ratioed with the reference event waveforms). Of the 1296 events processed, only 598 (46%) had been cataloged by the NCSN, and of these, only 284 (22%) had had event magnitudes determined. Hence, an ~ 4.5-fold increase in the number of similar events with both locations and magnitudes was realized with this test set of 25 reference events. Furthermore, the locations and magnitudes were determined with a minimum of analyst time (primarily only routine cataloging of the 25 reference events) and with both routine and high-precision resolution (see Figure 2 and discussion in section on “Additional Information, Comments and Suggestions”). Because the detections are cross-correlation based, there are also almost no detection or picking errors commonly associated with false STA/LTA triggering.

Even more significant than the increased number and high-precision cataloging of these small events is their utility for fault zone monitoring and a variety of other quality control and research applications. For example once a reference event has been defined and its pattern processed and scanned through the backlog of continuous data, its catalog of similar events can easily be updated for monitoring purposes by applying the automated procedures we have developed to newly recorded data. Three of the 25 reference events we are testing (i.e., reference events from the three SAFOD target sequences, HI, SF and LA) are regularly updated in this way in support of the SAFOD experiment.

The similar events associated with each reference event can also be automatically decomposed further into subsets of characteristically repeating microearthquake sequences (groups of nearly collocated and similar magnitude events occurring repeatedly over many years) whose waveforms over time provide a history of channel responses to near identical repeating earthquake sources across the entire network. When such characteristic repeats occur, it is a simple matter of waveform comparison of the recent repeat with previous repeats on a particular channel to identify problematic channel response. Though not yet developed, such waveform comparisons also readily lend themselves to automated processing that could ultimately give automated alarms providing rapid notification of less than optimal performance, even when only partial degradation in response occurs (e.g., degradation that occurs only within limited frequency band). Due to the nature of our processing approach, larger timing errors (i.e. those exceeding 0.1 sec.) also manifest themselves.

The characteristic repeating earthquake sequences (CS) can be used in a variety of other monitoring and research applications as well. For example by serving as repeating illumination sources at depth, CS events can be used for monitoring temporal change a variety of seismic wave propagation attributes (e.g., velocity, anisotropy, fault zone guided waves (FZGWs), and the migration of individual coda scatterers). The recurrence times and relative magnitudes among CS repeats can also be used for studies of earthquake scaling, testing of time-dependent earthquake forecast models or for inferring fault zone creep rates at depth. Pairs of similar yet non-characteristic events can also be used for investigations of source parameter scaling using a smaller event from a pair as a Green's to be deconvolved from the larger event leaving a picture of the larger events slip distribution.

Because of these and other potential uses for the similar event data that we have compiled to date, our plans are to make this test catalog of similar events available to the community on-line through the NCEDC. We also hope to continue to update the 25 reference event catalogs regularly through funds obtained from proposed research grants and to incorporate results from the updates into a more formal quality control structure to supplement our existing SOH monitoring efforts. Expansion of the catalog to include more reference sequences to increase the frequency of similar event sampling for SOH and research is also being considered.

Data Management Practices (2008)

Data from all NHFN and HRSN stations are telemetered in real-time to the Northern California Earthquake Data Center at UC Berkeley. Telemetry paths vary from station to station, but when things are working well, most data arrive within 5 s of their timestamp, and are immediately available for real-time processing (Standard 4.1). At the same time, they are made available to external users in the data center's DART (Data Available in Real Time) buffer (Standard 5.1). U.C. Berkeley Seismological Laboratory (BSL) staff are available to deal with telemetry problems 24/7, to ensure that real-time data collection is impeded as little as possible. If there are gaps in the data center's collection, missing data are retrieved from the station when telemetry resumes.

As they arrive at the data center, data from the NHFN and HRSN stations are automatically fed into processing streams designed to pick phases (Standard 4.3). Phase picks are available shortly after the data's arrival, in general within 10 s. We have implemented RAD processing on the real-time system, to continuously produce picks, which we are exchanged with USGS Menlo Park. Automated amplitude information for the borehole networks is not currently provided in near-real-time and awaits a more robust methodology for scaling amplitudes from borehole sensors (that are of variable depths and whose high gain recordings can severely clip on near-by moderate and large earthquakes) for magnitude determinations (Standard 4.2).

The BSL and the USGS Menlo Park share earthquake reporting responsibility for Northern California through the Northern California Seismic System (NCSS). The NHFN and HRSN data streams come into the BSL in real-time and are contributed to the NCSS for event processing. Event times and locations from the NCSS are usually made public within 15 s of an earthquake detected by the combined networks (Standard 5.1). Parameters for events at or beyond the combined networks' edges may be somewhat delayed (30 s). Various magnitude types are determined with coda magnitudes (M_d) taking possibly as long as several minutes. For events of magnitude 3.0 and greater, local magnitude (M_L) is calculated within 30 s of M_d, and moment magnitude (M_w) within 5 minutes of the origin time (i.e., when applicable and possible). Event information is stored automatically in a database. Our earthquake processing system is currently in transition to the CISN software. As a result, catalog information for old events (before Nov 29, 2006) is stored in flat-files, while for new events it is stored in the database. The "Event bulletin" – the catalog that includes both current and historical data – is being updated hourly with recent information from the database. When the transition is complete, users will be able to retrieve the most up-to-date catalog information from the database at any time (Standard 5.2).

Metadata are current and publicly available via the *SeismiQuery* software (Standard 5.3). Metadata information for all NHFN and HRSN stations is maintained by the NCEDC where care is taken to update the metadata quickly when equipment has been changed. We also QC the metadata regularly using large teleseisms to confirm the expected response to ground motion is consistent across the network.

Data from the NHFN and HRSN stations is stored in the archives of the NCEDC (Standard 5.4). Real-time data becomes available there almost immediately. The real-time data are replaced with quality checked data (completeness, timing problems corrected), usually within 3-5 days of their production.

Continuity of Operations and Response Planning (2008)

The BSL collects, processes and archives the NHFN and HRSN data. Consequently all the continuity and response planning efforts implemented by the BSL also apply to the NHFN and HRSN data flow. These include archival of the data in a "quake-safe" building, UPS, a generator with fuel for 4-7 days, master and slave data acquisition computers and real-time processing computers. In addition each NHFN station has 1-day of data storage capacity in case of telemetry failures. A central site data collection node also exists at Parkfield for the HRSN where several weeks worth of local data storage capacity and emergency UPS and a backup generator are maintained for coping with power and communication failures.

Progress on Metadata Development (2008)

Current metadata information for all NHFN and HRSN stations (including response information) are maintained and available through the NCEDC where care is taken to update the metadata quickly when equipment has been changed. The metadata is publicly available over the web through the NCEDC via *SeismiQuery* software (http://www.ncedc.org/SeismiQuery) (Standard 5.3). Metadata information is also regularly quality checked using large teleseisms to confirm that the expected response to ground motion is consistent across all the NHFN, HRSN and the BSL's BDSN stations.

Data from the NHFN and HRSN stations is stored in the archives of the NCEDC (Standard 5.4). Real-time data becomes available there almost immediately. The real-time data are replaced with quality checked data (completeness, timing problems corrected), usually within 3-5 days of their production.

Table 1. Summary Statistics for Regional/Urban Seismic Network (to Nov. 2008) This table contains combined information for both the NHFN and HRSN for stations that are currently fully operational. Four additional NHFN borehole stations are instrumented and in their final stages of infrastructure installation (see NHFN subsection on New stations).

Total no. of stations operated and/or recorded	**28**
Total no. of channels recorded	**691**
No. of short-period (SP) stations	**28**
No. of short-period (SP) stations with metadata	**28**
No. of broadband (BB) stations	**0**
No. of broadband (BB) stations with metadata	**0**
No. of strong-motion (SM) stations	**8**
No. of strong-motion (SM) stations with metadata	**8**
No. of stations maintained & operated by network	**28**
-same, with full metadata	**28**
No. of stations maintained & operated as part of ANSS	**22**
-same, with full metadata	**22**
Total data volume archived (mbytes/day)	**2160**

Table 2. Earthquake Data and Information Products

Network Products		
Does the network provide the following?	**Yes/No**	**Comments/Explanation**
Primary EQ Parameters		
Picks	Yes	Through NCSS
Hypocenters	Yes	Through NCSS
Magnitudes (& Amplitudes)	Yes	Through NCSS
Focal mechanisms	Yes	Through NCSS
Moment Tensor(s)	No	Borehole waveforms do not contribute to moment tensors
Other EQ Parameters/Products		
ShakeMap	Yes	Through NCSS
Finite Fault	Yes	Through NCSS
Supplemental Information		
Felt Reports	Yes	We encourage people to submit to the CIIM website
Event Summary	Yes	Through NCSS
Tectonic Summary	No	
Collated Maps	No	
Refined Hypocenters (e.g. double-difference)	No	Automated high-precision cataloging procedures and software have been developed for similar and repeating microearthquakes. Test catalog
Web Content		
Recent EQ Maps	Yes	CISN – with USGS MP
Station Helicorder	No	
Station noise PDFs	Yes	
Station Performance Metrics	Yes	
Network Description	Yes	NCEDC website links

Network Products		
Does the network provide the following?	**Yes/No**	**Comments/Explanation**
Station List	Yes	NCEDC website links
Station Metadata	Yes	NCEDC/SeismiQuery
Email Notification Services	Yes	For moment tensors primarily
Contact Info	Yes	
Region-specific FAQs	No	
Region-specific EQ info	Yes	
Waveforms		
Triggered	Yes	
Continuous	Yes	
Processed	Yes	We provide V0 data to the SMEC and the NSMEDC within 24 hours of an event
Summary Products		
Catalogs	Yes	From NCSS processing
Metadata		
Instrument Response	Yes	
Site Info (e.g. surface geology, Vs30)	No	

Descriptions:

Tectonic Summary: Text and/or figures describing the tectonic setting of the event and related activity

Event Summary: Text and/or figures (press releases, collated media/disaster agencies info) that describes the earthquake and its effects

Collated Maps: Any map or set of maps that illustrates the event properties, tectonics, hazards, etc

Processed Waveforms: Specialized processing that is required by some portion of the community, e.g. processed strong motion records for the engineering community

Catalogs: Lists of parameters that describe an earthquake(s) or information used to describe an earthquake (e.g., picks, locations, amps,..)

Network Products		
Does the network provide the following?	**Yes/No**	**Comments/Explanation**
Region-specific earthquake information: **Description (text and/or maps) of historical earthquakes, faults/geology, etc.**		

Appendix A: ANSS Cooperating Network Performance Self-Rating

Question	Answer	Explanation (if needed)
1. What is the minimum magnitude detection threshold for your network?	< 0.8 M_d	We cooperate with the USGS Menlo Park to form the NCSS. Together, we detect and locate quakes with magnitudes below M_d 0.8
2. What is the minimum magnitude detection threshold for the best instrumented part of your network?	< 0.8 M_d	We cooperate with the USGS Menlo Park to form the NCSS. Together, we detect and locate quakes with magnitudes below M_d 0.8 (the lower limit of M_d)
3. What is the typical hypocentral location accuracy for earthquakes occurring within your network? Is it the same for automated vs. reviewed?	~ 500 m or less	yes
4. Does your network report automated earthquake locations into QDDS? If yes, how long does it take?	yes	It depends on the location. The initial report can be 15-30 s after the event.
5. Does your network report analyst-reviewed earthquake locations for all quakes into QDDS (i.e., the little ones)?	not yet	We await the CISN software to extend reporting. If yes, what is the typical processing delay?
7. Describe the velocity model used to locate earthquakes in your network (1-D?, multiple models?, 3-D?). Does it differ for automated vs. reviewed?	currently multiple models	no
8. What software/program does your network use to locate earthquakes? Does it differ for automated vs. reviewed?	hypo inverse	no.
9. What magnitudes does your network routinely report in real time (Md, ML, Me, Mw, Ms etc.)? How long does it take to compute them?	M_d, M_L, M_w	M_d depends on event size, up to 4 minutes M_L 30 s after M_d M_w 5 minutes after origin time
10. Does your network archive phase information at a datacenter?	yes	If yes, how long is the delay to report? immediate In what year does archiving begin? 2004 for HRSN; 2007 for NHFN Where is the information archived? NCEDC

Appendix A: ANSS Cooperating Network Performance Self-Rating

Question	Answer	Explanation (if needed)
11. Does your network archive summary (i.e., earthquake catalog) information at a public datacenter?	yes	If yes, how long is the delay to report? Immediate In what year does archiving begin? 1987 for HRSN; 2007 for NHFN
12. Does your network archive event waveforms at a public datacenter?	yes	If yes, describe what type of channels (e.g., EH, HH, HN) and how long is the delay to report? NHFN: DP,BP,LP,CL,BL,LL, EP HRSN: DP,BP Currently data is telemetered in real-time and is generally available for external users through the NCEDC's DART system within 5 to 10 sec. In what year does archiving begin?
13. Do you archive continuous waveforms at a public datacenter?	yes	If yes, describe which channels and how long is the delay to report? NHFN: BP,LP,BL,LL HRSN: DP,BP Delay 5-10 sec. In what year does archiving begin? NHFN: 1995 HRSN: 2001
14. If your network archives waveforms, does it supply supporting instrument response metadata to support generation waveforms in SEED? For all waveforms?	yes and yes	
15. Does your network compute focal mechanisms?	yes	Networks contribute to mechanisms through NCSS processing. If yes, what type (first motion, moment tensor). Moment Tensor. In real-time? Within ~5 minutes.

Appendix A: ANSS Cooperating Network Performance Self-Rating

Question	Answer	Explanation (if needed)
		Do you archive them at a public datacenter? yes
16. Does your network automatically distribute email to the public in near real-time for significant events?	no	If yes, Do you offer a website where they can sign up? We encourage them to go to ENS.
17. Does your network automatically distribute alphanumeric pages to the public in near real-time for significant events?	no	Not to the general public. Only to a select set of users. If yes, Do you offer a website where they can sign up? No. We encourage public to use
18. Does your network automatically compute *ShakeMaps* and make them publicly available? If so, how long does it take?	yes	Networks contribute to NCSS processing and subsequent ShakeMaps. Takes 5-10
19. Does your network operate a fault-tolerant system (e.g., redundant computers, UPS, back-up generator with lots of fuel)?	yes	In a "quake-safe" building, UPS, backup generator with fuel for 4-7 days, master and slave data acquisition computers and real-time processing computers.
20. What does your network do with the data recorded on ANSS strong motion instruments? For example, do you make it available to the engineering community through a Data Center?	yes	Strong motion data are stored in the NCEDC. V0 is prepared within 24 hours of a quake and sent to the National Strong Motion data center (Sacramento)

Additional Information, Comments and Suggestions (2008)

The NHFN and HRSN now contribute real-time data from 28 stations to California real-time seismic monitoring operations (i.e., through the NCSS processing stream) for response applications and collection of basic data for long-term hazards mitigation. In addition, these networks provide to the research community unique borehole recordings of very low amplitude seismic signals (e.g., from micro-earthquakes or non-volcanic tremor) at high gain and low noise. Data from the NHFN also provide down-hole accelerometer data that, in conjunction with surface strong motion recordings, provide important basic information on near surface amplification effects in the free-field and near critical structures in the heavily Urbanized Bay Area. Data from the HRSN also complements major research initiatives in the Parkfield-Cholame area of California (e.g. SAFOD (the San Andreas Fault Observatory at Depth) and PBO (Plate Boundary Observatory)) where intensive research on the recently discovered non-volcanic tremor phenomena and on the seismic and related properties of the deep San Andreas Fault zone are taking place.

Hence these networks are providing functionality for both real-time seismic monitoring applications and for cutting-edge research on fault zone and earthquake hazard related issues. We have also made significant strides towards reducing future land-owner costs for the HRSN component of the network (~ $9800/yr.). We have also now developed an automated similar and repeating event cataloging procedure for providing high-precision relative event location and magnitude catalogs for the numerous very small (down to below -0.5 Mw) similar and repeating microearthquakes that are not cataloged by the USGS's regional NCSN catalog (Figure 2). A test catalog of these data are have already shown promise for providing significant improvements in monitoring of the SOH of the HRSN, for supporting SAFOD efforts and for use in a variety of research applications. We feel, therefore, that the cost of continued operation of the borehole networks relative to the value of the data that they provide to the community is low.

ACCOMPLISHMENTS 2009-10

Northern Hayward Fault Network (NHFN):

Changes Implemented in 2009-10

New stations. Reorganization and transition of field engineering support and staff for the NHFN project was implemented this past year to facilitate NHFN development and as a result accelerated progress has been made on installation and development of new sites.

SM2B: Last year, in partnership with St. Mary's college and Caltrans, we completed the upgrade of our only post-hole (3.4 meter deep) site (SMCB) with a deep borehole (150.9 meter) installation (SM2B) at St. Mary's College. Since then the new site has remained on-line, contributing real-time data to the NCSS. This year (2009) considerable field effort has been undertaken to harden the site and knock down spurious noise sources. Consequently, the data currently being recorded by SM2B is now on par with the quality of borehole data from the other NHFN sites (Figure 3, bottom seismogram) and is of markedly better signal to noise than was available from the 3.4 meter post-hole installation.

RB2B: This new station is located at the toll plaza of the San Rafael-Richmond bridge and has been installed by the BSL in partnership with Caltrans. Previously at this site a deep borehole had been drilled and instrumented and installation of infrastructure, power and telemetry had been initiated. This year these efforts were completed and the site became operational and began sending data to the BSL for NCSS processing and NCEDC archiving in December of 2009 (Figure 3, top seismogram). Noise reduction efforts are now being carried out at this new site.

CMAB: This site at the California Maritime Academy near the Carquinez bridge was also installed by the BSL in partnership with Caltrans. Previously permitting and siting for this was completed. This year, drilling and sensor installation at this site took place in a 'hole of opportunity' mode (i.e., drilled and installed by an otherwise idle Caltrans drilling crew) and activation of the site was a strikingly rapid process. Exceptionally, telemetry at this site is allowing 6-channels of seismic data to be collected continuously at 500 samples-per-second. The site replaces a particularly noisy and shallow NHFN backbone borehole station at the south end of the Carquinez bridge (CRQB), and before decommissioning of the noisy CRQB site, two months of data from both sites was collected and compared. With these overlapping data sets, the signal and background noise levels between CMAB and CRQB were compared to access the relative performance of the two HFN borehole stations (Figure 3, 2nd and 3rd seismograms from top, respectively, and Figure 4). The two stations are located on the northern and southern sides of the Carquinez Bridge, respectively. The records in Figure 3 show the stations' response to the deep focus teleseismic Mw 6.9 event: 2010/02/18 01:13:19 42.5870 6.90 Mw, which occurred on February 18, 2010. The inferred P-wave arrival on vertical geophone components' (DP1) absolute ground accelerations in the 0.6-3.5 Hz BP are shown. The P-wave signal strength at CRQB are low and can be attributed to the difference in the depth of the CRQB borehole relative to that of CMAB. CRQB is also very noisy and the P-wave peak signal level (barely perceptible) is approximately half of the signal level at CMAB.

Power Spectral Density (PSD) noise plots for the two stations were also compared (Figure 4). The station CMAB's performance is clearly superior with an observed background noise PSD level at ~30 dB below the corresponding noise level at CRQB at frequencies above ~1.2 Hz. Also the CMAB PSD has some apparent structure with peaks at ~0.3, ~0.9, ~3 and ~12 Hz which may(?) be related to modes of the new Carquinez Bridge. Before smoothing (not shown) a large signal contamination at 60 Hz and its harmonics are also apparent and most likely do to direct induction of the 60 Hz signal from an adjacent high-tension power lines. Noise reduction efforts (e.g., shielding and a revised grounding scheme) are now being carried out at this new site to knock down these noise signals.

PINB: With Caltrans funding, we have also purchased velocity and acceleration sensors and instrumentation for 2 additional sites, and Caltrans will provide drilling for these sites as spare drilling crew time becomes available (i.e., holes of opportunity). Permit negotiations for one of these sites (PINB, shown in Figure 1a) was completed this year. These complex negotiations involved (among others) the East Bay Regional Parks District and UNAVCO and give permission to create borehole site PINB at Pt. Pinole Regional Park. However, during these negotiations it was recognized that installation of a deep borehole at this site is potentially problematic due to environmental issues (in the past, the Park had been a dynamite manufacturing facility, leaving the possibility that liberation of chemical contaminants may occur from extraction of borehole materials during drilling). We are currently in the process of evaluating the situation further to decide whether or not the PINB installation will need to be abandoned in favor of an alternative future site (possibly at a location near the 580/680 freeway interchange in the East Bay).

E07B and W05B: Negotiations with Caltrans also continue to bring on-line these two additional borehole sites along the Bay Bridge where permanent deep borehole sensors had been deployed and operated in a short-term survey mode for an experiment that had previously been completed. The permanently installed borehole sensors remain in place in the deep boreholes and still test as operational. Negotiations continue to obtain funds to reactivate these sites with modern recording and real-time telemetry to provide NCSS and research grade monitoring capabilities. It is hoped that these sites can be brought on-line as the retrofit projects on the Bay Bridge are completed.

Partnerships and Additional and Continuing Caltrans Funding Efforts.

Operation of this Bay Area borehole network is funded by the ANSS and through a partnership with the California Department of Transportation (Caltrans). ANSS provides operations and maintenance (O&M) support for a fixed subset of 9 operational stations that were initiated as part of previous projects in which the USGS was a participant. Caltrans provides developmental and O&M support for an additional 10 stations that have been or are in the process of being added to the network with Caltrans partnership grants. Caltrans also continues to provide additional support for upgrade and expansion when possible. The NHFN is also heavily leveraged through partnerships with various institutions, and we have continued to nurture and expand these relationships. Over the past year we have continued our collaborative partnerships with Caltrans, St. Mary's College, the Cal Maritime Academy, the East Bay Parks District, UNAVCO, Lawrence Berkeley National Laboratory, and non-ANSS components of the USGS.

This year the California budget crisis jeopardized continued funding of our agreement with Caltrans for O&M of the Caltrans supported component of the NHFN. After considerable effort we were fortunately able to reinstate partial support for the O&M, pending further review by Caltrans. On June 25 of 2010 a meeting was held with interested parties at Caltrans to more clearly define the NHFN's role in Caltrans projects and to develop strategies for obtaining future support for NHFN project activities. The Caltrans contingent was impressed with the placement of the deep NHFN borehole sensors' in bedrock, and there was clearly interest at supplementing the NHFN borehole seismometers with surface strong motion sensors. In addition, considerable interest was shown in supporting reactivation of several previously abandoned borehole stations on critical Caltrans structures. Strategies revolving around which specific entities within Caltrans to whom future funding requests should be made were also discussed and we are currently in the process of solidifying plans for making such requests.

High Resolution Seismic Network (HRSN):

Routine maintenance tasks required this year to keep the HRSN in operation include cleaning and replacement of corroded electrical connections; grounding adjustments; cleaning of solar panels; re-seating, resoldering, and replacement of faulty pre-amp circuit cards; testing and replacement of failing batteries; and insulation and painting of battery and data logger housings to address problems with low power during cold weather. Remote monitoring of the network's health using the Berkeley Seismological Laboratory's SeisNetWatch software is also performed to identify both problems that can be resolved over the Internet (e.g. rebooting of data acquisition systems due to clock lockups, etc.) and more serious problems requiring field visits. Over the years, such efforts have paid off handsomely by providing optimally complete and exceptionally low noise recordings of continuous very low amplitude seismic signals produced by microearthquakes (below magnitude 0.0Ml) and nonvolcanic tremors.

The network connectivity over the T1 circuit also allows remote monitoring of various additional measures of the state of health (SOH) of the network in near-real-time, such as background power spectral density (PSD) noise levels. By periodically evaluating PSDs, we can rapidly evaluate, through comparison with previously PSD information, changes in the network's station response of seismic signals across the wide band high-frequency spectrum of the borehole HRSN sensors. Changes in the responses often indicate problems with the power, telemetry, or acquisition systems, or with changing conditions in the vicinity of station installations that are adversely effecting the quality of the recorded seismograms. Once state of health issues are identified with the various additional measures of SOH, further remote tests can be made to more specifically determine possible causes for the problem, and corrective measures can then be planned in advance of field deployment within a relatively short period of time.

JCNB Outage: an update. In the Spring of 2008, signals from HRSN station JCNB began showing signs of deterioration. Shortly thereafter, data flow from this station stopped completely. Field investigation showed that the borehole sensor and cable had been grouted to within ~34 feet of the surface and that a rodent had found itself trapped in the upper 34 foot void space and chewed through the cable, thus severing the connection to the deep borehole package. At this time, costs for reestablishing connection to the cable at depth have been prohibitive, and it is also likely that the grouted-in sensor has been compromised by fluids running down the exposed cable. Hence, plans are being made to substitute either a surface seismometer or a borehole sensor package within the open 34 foot section of the borehole to provide continued seismic coverage at the JCNB site. A long-idle sensor package has been identified as a possible replacement and it is now being assessed by BSL's engineering group to confirm functionality.

Major Telemetry Restructuring.
In recent years increased scientific activity in the rural Parkfield area due to SAFOD has lead to an increased demand for site access and development on privately owned property and a corresponding increase in access fees charged by private land owners. As a result, land use fees paid by the HRSN project had increased dramatically from less than $1000 annually prior to the SAFOD effort to over $14,000 annually. This represents over 15% of the entire HRSN budget with no corresponding increase in support from the project's funding agency. To compensate for the increased landowner costs, maintenance efforts had to be cut back, and as a result, network performance suffered. To help alleviate the problem, last year we implemented (through cooperation with the USGS) plans to minimize our dependence on access to private lands. This primarily involved establishing alternative telemetry paths for roughly half of the HRSN sites.

To date, telemetry paths for five HRSN sites (SMNB, CCRB, MMNB, VARB, and SCYB) are completely redirected from the Gastro Peak relay site to an alternative relay site at Hogs Canyon (HOGS) through an agreement with the USGS. Telemetry of GHIB data has also been redirected from Gastro Peak through an alternative path. Plans to redirect telemetry of an additional site from Gastro Peak (LCCB) are being examined and field tested for viability. This year, the landowner again chose not to renew our access agreement for Gastro-Peak, saving us approx. $9800 in annual fees, but leaving suspended the issue of cutting off RMNB and LCCB telemetry. In the mean-time the owner has allowed us to continue operating one station (RMNB) located at the Gastro-Peak site free of charge for an unspecified period of time, though access to the site in the event of station failure has not been agreed upon. Until alternative telemetry is implemented, the RMNB station is also serving as as a repeater for station LCCB, so data flow from both LCCB and RMNB remains in jeopardy. We have remained in contact with the Landowner and in June 2010 we were asked by them to submit a proposal for terms allowing us access once again to RMNB and its LCCB repeater. Price has not yet been set and negotiations remain in a delecate state.

Similar Event Catalog: More Earthquakes and Application to SOH. We have now completed the software development and testing of our semi-automated similar event detection and cataloging scheme based on cross-correlation scans of continuous HRSN data. The method uses a small number of reference events whose waveforms, picks, locations, and magnitudes have been accurately determined, and it automatically detects, picks, locates, and determines magnitudes for events similar to the reference event to the level of relative accuracy and precision that only relative event analysis can bring.

We have now applied the methodology using a set of 34 reference events from diverse locations within the HRSN coverage and scanned these events through continuous seismic records from July 27, 2001 through April 10, 2010 (spanning both the M6.5 San Simeon and M6 Parkfield earthquakes). Scanning of the reference events yielded over 3200 unique similar event detections that were then processed using highly automated procedures to yield high-precision picks, routine and relative event relocations, and precise magnitude estimates (using low frequency spectra ratioed with the reference event waveforms). Of the 3200+ events processed, only about 45% had been cataloged by the NCSN, and of these, only slightly over 20% had had event magnitudes determined. Hence, an ~ 4.5- to 5-fold increase in the number of similar events with both locations and magnitudes was realized with this set of 34 reference events. Furthermore, the locations and magnitudes were determined with a minimum of analyst time (primarily only routine cataloging of the 34 reference events, which needs be done only once) and with both routine and high-precision resolution (see Figure 2 and discussion in section on "Additional Information, Comments and Suggestions"). Because the detections are cross-correlation based, there are also almost no detection or picking errors commonly associated with false STA/LTA triggering.

In addition to the increased number and high-precision cataloging of these small events, their utility for state of health (SOH) monitoring and quality control applications is also very apparent. Once a reference event has been defined and its pattern processed and scanned through the backlog of continuous data, its catalog of similar events can easily be updated for SOH monitoring purposes by applying the automated procedures we have developed to newly recorded data.

For example, the similar events associated with each reference event can be automatically decomposed further into subsets of characteristically repeating microearthquake sequences (groups of nearly collocated and similar magnitude events occurring repeatedly over many years) whose waveforms over time provide a history of channel responses to near identical repeating earthquake sources across the entire network. When such characteristic repeats occur, it is a simple matter of waveform comparison of the recent repeat with previous repeats on a particular channel to identify problematic channel response. Such waveform comparisons also readily lend themselves to automated processing that could ultimately give automated alarms providing rapid notification of less than optimal performance, even when only partial degradation in response occurs (e.g., degradation that occurs only within limited frequency band). Due to the nature of our processing approach, larger timing errors (i.e. those exceeding 0.1 sec.) also manifest themselves.

As an illustration consider Figure 5. It shows that on March 3, 2006, the DP1 channel was experiencing significant high amplitude step-decay spiking (due to pre-amp malfunction) and that on August 22, 2008 the signal amplitude was greatly attenuated (due to excess tension and separation of the signal cable wiring). Armed with this type of information, field engineers can quickly identify and address major problems. In addition to a visual assessment, the extreme similarity of the events lends itself to the application of differencing techniques in the time and frequency domains to automatically identify detailed SOH issues on all channels within a network.

Repeating sequences with earthquakes in this magnitude range (M0 to M2) generally light up the entire contingent of HRSN stations and typically repeat every 1 to 2 years. Hence because we are monitoring 34 sequences, evaluations of this type can be made on average approximately every 3-weeks on an automated basis. However, there are on the order of 200 such sequences known in the Parkfield area, leaving the ultimate possibility that automated SOH analyses could take place every 2 to 3 days.

For other networks recording continuously in the Parkfield area (e.g., NCSN, BDSN) it would also a relatively simple process to extend the SOH analysis using characteristic repeating events to their stations. Furthermore, numerous repeating event sequences are also know to exist in the San Francisco Bay and San Juan Bautista Areas were continuous recording takes place. Hence application of the repeating event SOH technique to these zones should also be feasible.

We are continuing to expand the number of pattern events (unfunded by the cooperative agreement subsequent to this one) and resulting multi-year scans to increase the frequency of sampling of similar and repeating event sequences for SOH purposes and for expanding the catalog of very small similar and repeating microearthquakes (down to Mp of -0.5). We are also adapting the codes to take advantage of faster computing now available.

Further development of the similar event processing approach also holds promise in other applications where automated and precise monitoring of bursts of seismic activity to very low magnitudes is desirable (e.g. in aftershock zones or in volcanic regions) or where automated updates of preexisting repeating sequences and their associated deep slip estimates are desired.

Tremor Monitoring. The HRSN data played an essential role in the discovery of nonvolcanic tremors along the San Andreas Fault (SAF) below Cholame, CA (Nadeau and Dolenc, 2005). The Cholame tremors also occupy a critical location between the smaller Parkfield (~M6) and much larger Ft. Tejon (~M8) rupture zones of the. Because the time-varying nature of tremor activity is believed to reflect time-varying deep deformation and presumably episodes of accelerated stressing of faults, because an anomalous increase in the rate of Cholame tremor activity preceded the 2004 Parkfield M6 by ~21 days, and because periodic episodes and continued elevated tremor activity have continued since the 2004 Parkfield-Cholame and Monarch Peak areas (Nadeau and Guilhem, 2009), we are continuing to monitor the tremor activity observable by the HRSN to look for anomalous rate changes that may signal an increased likelihood for another large SAF event in the region.

Efforts in Support of SAFOD. An intensive and ongoing effort by the EarthScope component called SAFOD (San Andreas Fault Observatory at Depth) has been underway to drill through, sample, and monitor the active San Andreas Fault at seismogenic depths and in very close proximity (within a few 10s of km or less) of a repeating magnitude 2 earthquake site. The HRSN data plays a key role in these efforts by providing low noise and high sensitivity seismic waveforms from active and passive sources, and by providing a backbone of very small earthquake detections and continuous waveform data with station coverage that is complementary to the SAFOD pilot and mainhole seismometers.

In early September, 2007, SAFOD drilling had penetrated the fault near the HI repeating target sequence and collected core samples in the fault region that presumably creeps and surrounds the repeatedly rupturing HI patch. Unfortunately, due to complications during drilling, penetration and sampling of the fault patch involved in repeating rupture was not possible. Long-term monitoring efforts of the ongoing chemical, physical, seismological, and deformational properties in the zone (particularly any signals that might be associated with the next repeat of the SAFOD repeating sequences) are now in progress.

HRSN activities this year have contributed in three principal ways to these and longer-term SAFOD monitoring efforts: 1) Integration and processing of the HRSN data streams with those from the NCSN in the Parkfield area continues, effectively doubling the number of small events available for monitoring seismicity in the target zone and for constraining relative locations of the ongoing seismic activity. 2) Telemetry of all HRSN channels (both 20 and 250 sps data streams) continues to flow directly from Parkfield, through the USGS Parkfield T1 and the NCEMC T1, to the USGS and the BSL for near-real-time processing, catalog processing, and data archiving on the web-based NCEDC. This also provides near immediate access of the HRSN data to the SAFOD community without the week- or month-long delay associated with the previous procedure of having to transport DLT tapes to Berkeley to upload and quality check the data.

3) We have also continued to apply our prototype similar event automated catalog approach to the primary, secondary, and tertiary SAFOD target zones as a continued effort to monitor the SAFOD target zone activity at very high relative location precision.

These efforts and the free access of HRSN waveform data to the SAFOD seismology group, confirmed the latest repeat of the HI sequence on Aug 29 or 2008. Our monitoring efforts were also the first to report repeats of the SF and LA sequences occurring on December 19 and 20, 2008, respectively. Of particular interest were the SF and LA repeats which were recorded on the SAFOD main hole seismometer which had been installed in October. As of April 10, 2010, no additional repeats of the SF, LA, nor HI sequences have been detected, however, 9 events similar in waveform but located slightly off of these target sites have occurred and been cataloged since the previous repeats of these sequences.

Data Management Practices (2009-10)

Data from all NHFN and HRSN stations are telemetered in real-time to the Northern California Earthquake Data Center at UC Berkeley. Telemetry paths vary from station to station, but when things are working well, most data arrive within 5 s of their timestamp, and are immediately available for real-time processing (Standard 4.1). At the same time, they are made available to external users in the data center's DART (Data Available in Real Time) buffer (Standard 5.1). U.C. Berkeley Seismological Laboratory (BSL) staff are available to deal with telemetry problems 24/7, to ensure that real-time data collection is impeded as little as possible. If there are gaps in the data center's collection, missing data are retrieved from the station when telemetry resumes.

As they arrive at the data center, data from the NHFN and HRSN stations are automatically fed into processing streams designed to pick phases (Standard 4.3). Phase picks are available shortly after the data's arrival, in general within 10 s. We have implemented RAD processing on the real-time system, to continuously produce picks, which we are exchanged with USGS Menlo Park. Automated amplitude information for the borehole networks is not currently provided in near-real-time and awaits a more robust methodology for scaling amplitudes from borehole sensors (that are of variable depths and whose high gain recordings can severely clip on near-by moderate and large earthquakes) for magnitude determinations (Standard 4.2).

The BSL and the USGS Menlo Park share earthquake reporting responsibility for Northern California through the Northern California Seismic System (NCSS). The NHFN and HRSN data streams come into the BSL in real-time and are contributed to the NCSS for event processing. Event times and locations from the NCSS are usually made public within 15 s of an earthquake detected by the combined networks (Standard 5.1). Parameters for events at or beyond the combined networks' edges may be somewhat delayed (30 s). Various magnitude types are determined with coda magnitudes (M_d) taking possibly as long as several minutes. For events of magnitude 3.0 and greater, local magnitude (M_L) is calculated within 30 s of M_d, and moment magnitude (M_w) within 5 minutes of the origin time (i.e., when applicable and possible). Event information is stored automatically in a database. Our earthquake processing system is currently in transition to the CISN software. As a result, catalog information for old events (before Nov 29, 2006) is stored in flat-files, while for new events it is stored in the database. The "Event bulletin" – the catalog which includes both current and historical data – is being updated hourly with recent information from the database. When the transition is complete, users will be able to retrieve the most up-to-date catalog information from the database at any time (Standard 5.2).

Metadata are current and publicly available via the *SeismiQuery* software (Standard 5.3). Metadata information for all NHFN and HRSN stations is maintained by the NCEDC where care is taken to update the metadata quickly when equipment has been changed. We also QC the metadata regularly using large teleseisms to confirm the expected response to ground motion is consistent across the network.

Data from the NHFN and HRSN stations is stored in the archives of the NCEDC (Standard 5.4). Real-time data becomes available there almost immediately. The real-time data are replaced with quality checked data (completeness, timing problems corrected), usually within 3-5 days of their production.

Continuity of Operations and Response Planning (2009-10)

The BSL which collects, processes and archives the NHFN and HRSN data. Consequently all the continuity and response planning efforts implemented by the BSL also apply to the NHFN and HRSN data flow. These include archival of the data in a "quake-safe" building, UPS, a generator with fuel for 4-7 days, master and slave data acquisition computers and real-time processing computers. In addition each NHFN station has 1-day of data storage capacity in case of telemetry failures. A central site data collection node also exists at Parkfield for the HRSN where several weeks worth of local data storage capacity and emergency UPS and a backup generator are maintained for coping with power and communication failures.

Progress on Metadata Development (2009-10)

Current metadata information for all NHFN and HRSN stations (including response information) are maintained and available through the NCEDC where care is taken to update the metadata quickly when equipment has been changed. The metadata is publicly available over the web through the NCEDC via *SeismiQuery* software (http://www.ncedc.org/SeismiQuery) (Standard 5.3).

Metadata information is also regularly quality checked using large teleseisms to confirm that the expected response to ground motion is consistent across all the NHFN, HRSN and the BSL's BDSN stations.

Data from the NHFN and HRSN stations is stored in the archives of the NCEDC (Standard 5.4). Real-time data becomes available there almost immediately. The real-time data are replaced with quality checked data (completeness, timing problems corrected), usually within 3-5 days of their production.

Table 1. Summary Statistics for Regional/Urban Seismic Network (thru Jan. 2010)
This table contains combined information for both the NHFN and HRSN for stations that are currently fully operational. Two additional NHFN borehole stations are instrumented and in various stages of infrastructure installation (see NHFN subsection on New stations).

Total no. of stations operated and/or recorded	**29**
Total no. of channels recorded	**697**
No. of short-period (SP) stations	**29**
No. of short-period (SP) stations with metadata	**29**
No. of broadband (BB) stations	**0**
No. of broadband (BB) stations with metadata	**0**
No. of strong-motion (SM) stations	**9**
No. of strong-motion (SM) stations with metadata	**9**
No. of stations maintained & operated by network	**29**
-same, with full metadata	**29**
No. of stations maintained & operated as part of ANSS	**22**
-same, with full metadata	**22**
Total data volume archived (mbytes/day)	**2240**

Table 2. Earthquake Data and Information Products

Network Products		
Does the network provide the following?	**Yes/No**	**Comments/Explanation**
Primary EQ Parameters		
Picks	Yes	Through NCSS
Hypocenters	Yes	Through NCSS
Magnitudes (& Amplitudes)	Yes	Through NCSS
Focal mechanisms	Yes	Through NCSS
Moment Tensor(s)	No	Borehole waveforms do not contribute to moment tensors
Other EQ Parameters/Products		
ShakeMap	Yes	Through NCSS
Finite Fault	Yes	Through NCSS
Supplemental Information		
Felt Reports	Yes	We encourage people to submit to the CIIM website
Event Summary	Yes	Through NCSS
Tectonic Summary	No	
Collated Maps	No	
Refined Hypocenters (e.g. double-difference)	No	Automated high-precision cataloging procedures and software have been developed for similar and repeating microearthquakes. Test catalog
Web Content		
Recent EQ Maps	Yes	CISN – with USGS MP
Station Helicorder	No	
Station noise PDFs	Yes	
Station Performance Metrics	Yes	
Network Description	Yes	NCEDC website links

Network Products		
Does the network provide the following?	**Yes/No**	**Comments/Explanation**
Station List	**Yes**	**NCEDC website links**
Station Metadata	**Yes**	**NCEDC/SeismiQuery**
Email Notification Services	**Yes**	**For moment tensors primarily**
Contact Info	**Yes**	
Region-specific FAQs	**No**	
Region-specific EQ info	**Yes**	
Waveforms		
Triggered	**Yes**	
Continuous	**Yes**	
Processed	**Yes**	**We provide V0 data to the SMEC and the NSMEDC within 24 hours of an event**
Summary Products		
Catalogs	**Yes**	**From NCSS processing**
Metadata		
Instrument Response	**Yes**	
Site Info (e.g. surface geology, Vs30)	**No**	
Descriptions:		
***Tectonic Summary*: Text and/or figures describing the tectonic setting of the event and related activity**		
***Event Summary*: Text and/or figures (press releases, collated media/disaster agencies info) that describes the earthquake and its effects**		
***Collated Maps*: Any map or set of maps that illustrates the event properties, tectonics, hazards, etc**		
***Processed Waveforms*: Specialized processing that is required by some portion of the community, e.g. processed strong motion records for the engineering community**		
***Catalogs*: Lists of parameters that describe an earthquake(s) or information used to describe an earthquake (e.q., picks, locations, amps,..)**		

Network Products		
Does the network provide the following?	**Yes/No**	**Comments/Explanation**
Region-specific earthquake information: **Description (text and/or maps) of historical earthquakes, faults/geology, etc.**		

Appendix A: ANSS Cooperating Network Performance Self-Rating

Question	Answer	Explanation (if needed)
1. What is the minimum magnitude detection threshold for your network?	< 0.8 M_d	We cooperate with the USGS Menlo Park to form the NCSS. Together, we detect and locate quakes with magnitudes below M_d 0.8
2. What is the minimum magnitude detection threshold for the best instrumented part of your network?	< 0.8 M_d	We cooperate with the USGS Menlo Park to form the NCSS. Together, we detect and locate quakes with magnitudes below M_d 0.8 (the lower limit of M_d)
3. What is the typical hypocentral location accuracy for earthquakes occurring within your network? Is it the same for automated vs. reviewed?	~ 500 m or less	yes
4. Does your network report automated earthquake locations into QDDS? If yes, how long does it take?	yes	It depends on the location. The initial report can be 15-30 s after the event.
5. Does your network report analyst-reviewed earthquake locations for all quakes into QDDS (i.e., the little ones)?	not yet	We await the CISN software to extend reporting. If yes, what is the typical processing delay?
7. Describe the velocity model used to locate earthquakes in your network (1-D?, multiple models?, 3-D?). Does it differ for automated vs. reviewed?	currently multiple models	no
8. What software/program does your network use to locate earthquakes? Does it differ for automated vs. reviewed?	hypo inverse	no.
9. What magnitudes does your network routinely report in real time (Md, ML, Me, Mw, Ms etc.)? How long does it take to compute them?	M_d, M_L, M_w	M_d depends on event size, up to 4 minutes M_L 30 s after M_d M_w 5 minutes after origin time
10. Does your network archive phase information at a datacenter?	yes	If yes, how long is the delay to report? immediate In what year does archiving begin? 2004 for HRSN; 2007 for NHFN Where is the information archived? NCEDC

Appendix A: ANSS Cooperating Network Performance Self-Rating

Question	Answer	Explanation (if needed)
11. Does your network archive summary (i.e., earthquake catalog) information at a public datacenter?	yes	If yes, how long is the delay to report? Immediate In what year does archiving begin? 1987 for HRSN; 2007 for NHFN
12. Does your network archive event waveforms at a public datacenter?	yes	If yes, describe what type of channels (e.g., EH, HH, HN) and how long is the delay to report? NHFN: DP,BP,LP,CL,BL,LL, EP HRSN: DP,BP Currently data is telemetered in real-time and is generally available for external users through the NCEDC's DART system within 5 to 10 sec. In what year does archiving begin?
13. Do you archive continuous waveforms at a public datacenter?	yes	If yes, describe which channels and how long is the delay to report? NHFN: BP,LP,BL,LL HRSN: DP,BP Delay 5-10 sec. In what year does archiving begin? NHFN: 1995 HRSN: 2001
14. If your network archives waveforms, does it supply supporting instrument response metadata to support generation waveforms in SEED? For all waveforms?	yes and yes	
15. Does your network compute focal mechanisms?	yes	Networks contribute to mechanisms through NCSS processing. If yes, what type (first motion, moment tensor). Moment Tensor. In real-time? Within ~5 minutes.

Appendix A: ANSS Cooperating Network Performance Self-Rating

Question	Answer	Explanation (if needed)
		Do you archive them at a public datacenter? yes
16. Does your network automatically distribute email to the public in near real-time for significant events?	no	If yes, Do you offer a website where they can sign up? We encourage them to go to ENS.
17. Does your network automatically distribute alphanumeric pages to the public in near real-time for significant events?	no	Not to the general public. Only to a select set of users. If yes, Do you offer a website where they can sign up? No. We encourage public to use
18. Does your network automatically compute *ShakeMaps* and make them publicly available? If so, how long does it take?	yes	Networks contribute to NCSS processing and subsequent ShakeMaps. Takes 5-10
19. Does your network operate a fault-tolerant system (e.g., redundant computers, UPS, back-up generator with lots of fuel)?	yes	In a "quake-safe" building, UPS, backup generator with fuel for 4-7 days, master and slave data acquisition computers and real-time processing computers.
20. What does your network do with the data recorded on ANSS strong motion instruments? For example, do you make it available to the engineering community through a Data Center?	yes	Strong motion data are stored in the NCEDC. V0 is prepared within 24 hours of a quake and sent to the National Strong Motion data center (Sacramento)

Additional Information, Comments and Suggestions (2009-10)

The NHFN and HRSN now contribute real-time data from 29 stations to California real-time seismic monitoring operations (i.e., through the NCSS processing stream) for response applications and collection of basic data for long-term hazards mitigation. In addition, these networks provide to the research community unique borehole recordings of very low amplitude seismic signals (e.g., from micro-earthquakes or non-volcanic tremor) at high gain and low noise. Data from the NHFN also provide down-hole accelerometer data that, in conjunction with surface strong motion recordings, provide important basic information on near surface amplification effects in the free-field and near critical structures in the heavily Urbanized Bay Area. Data from the HRSN also complements major research initiatives in the Parkfield-Cholame area of California (e.g. SAFOD (the San Andreas Fault Observatory at Depth) and PBO (Plate Boundary Observatory)) where intensive research on the recently discovered non-volcanic tremor phenomena and on the seismic and related properties of the deep San Andreas Fault zone are taking place.

Hence these networks are providing functionality for both real-time seismic monitoring applications and for cutting-edge research on fault zone and earthquake hazard related issues. We have also made significant strides towards reducing future land-owner costs for the HRSN component of the network (~ $9800/yr.). We have also now developed an automated similar and repeating event cataloging procedure for providing high-precision relative event location and magnitude catalogs for numerous very small (down to below -0.5 Mw) similar and repeating microearthquakes that are not cataloged by the USGS's regional NCSN catalog (Figure 2). A test catalog of these data are have already shown promise for providing significant improvements in monitoring of the SOH of the HRSN (Figure 5), for supporting SAFOD efforts and for use in a variety of research applications. We feel, therefore, that the cost of continued operation of the borehole networks relative to the value of the data that they provide to the community is low.

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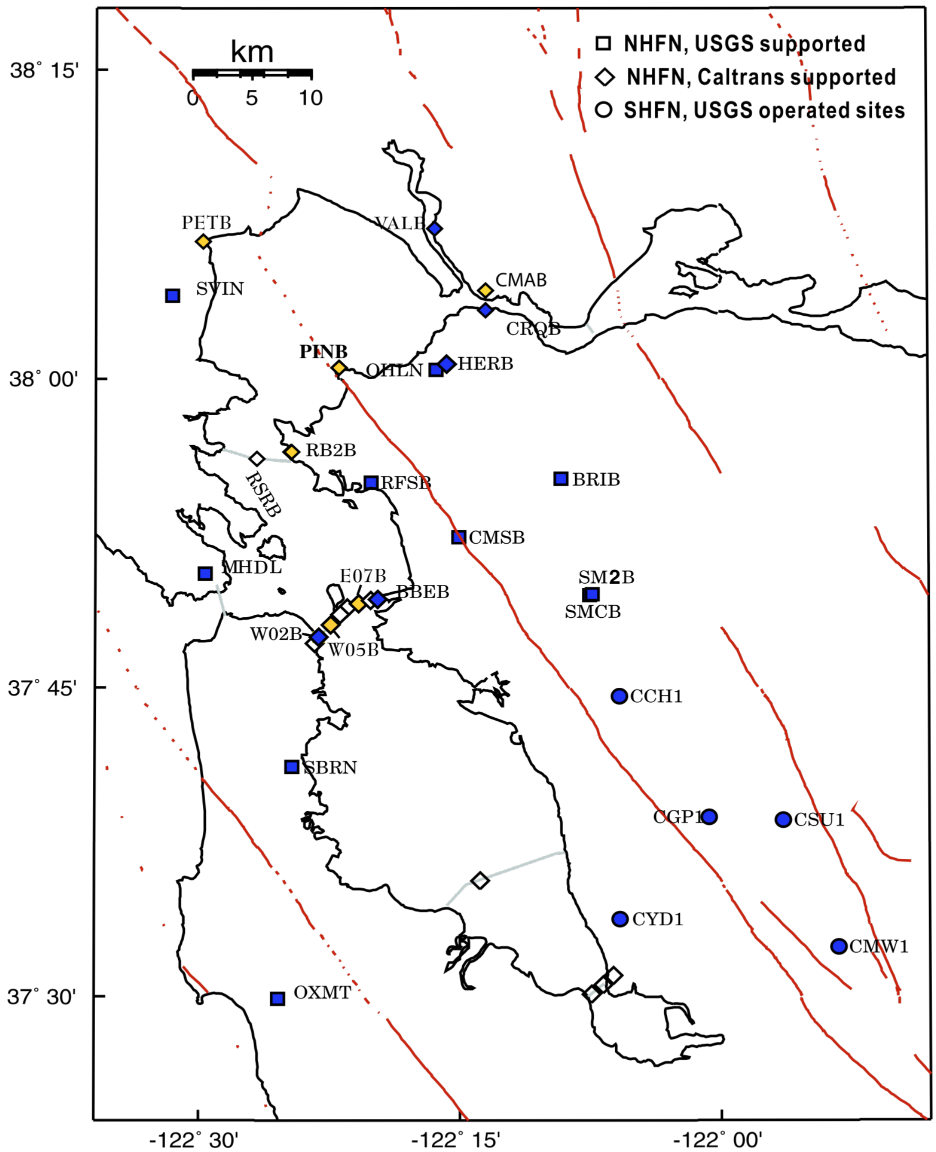

Figure 1a. Map of NHFN Seismic Stations. The squares show the 9 borehole sites funded through this cooperative agreement. Diamonds show Caltrans supported sites (blue-operational, yellow-in-progress, white-non-operational). All these stations provide short period high frequency broad-band width borehole recordings. Five MPBO (excluding BRIB which is already a NHFN station) stations have now been folded into the NHFN for a total of 19 NHFN stations. Links to the station lists of the MPBO and operating NHFN stations are:
http://seismo.berkeley.edu/bdsn/station_book/mpbo_station_book
http://seismo.berkeley.edu/bdsn/station_book/hfn_station_book
Circles show USGS SHFN operated sites (providing borehole coverage of the southeast bay but not funded through this cooperative agreement).

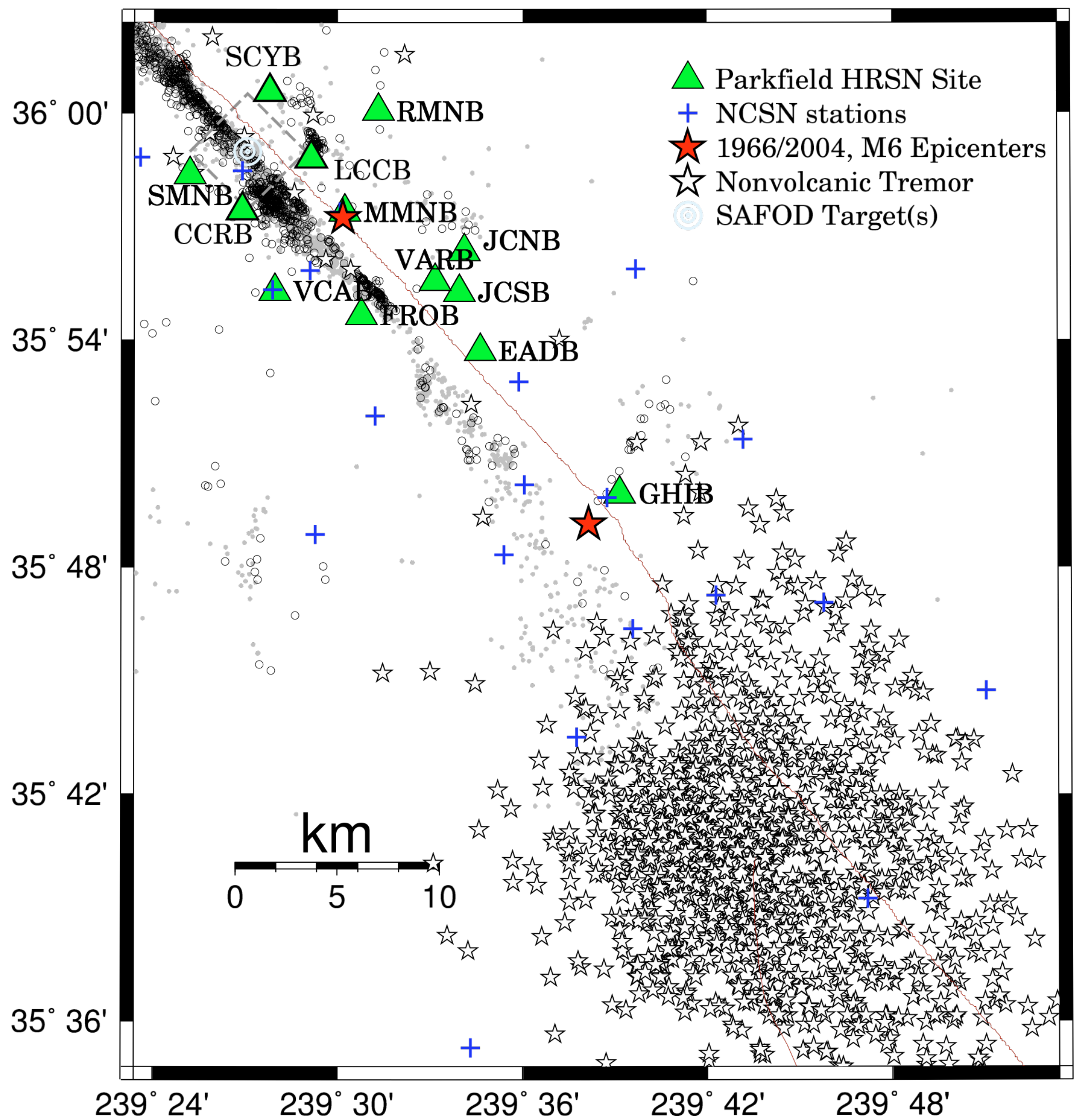

Figure 1b. Map showing the 13 HRSN stations, San Andreas Fault trace, locations of the repeating M2 SAFOD targets (light blue concentric circles within the 4 km by 4 km gray dashed box that surrounds the SAFOD zone), and the epicenters of the 1966 and 2004 M6 Parkfield main shocks. Also shown are recently discovered nonvolcanic tremors (white stars), earthquake locations. All these stations provide short period high frequency broad-band width borehole recordings. Link to HRSN station list is: http://www.ncedc.org/hrsn

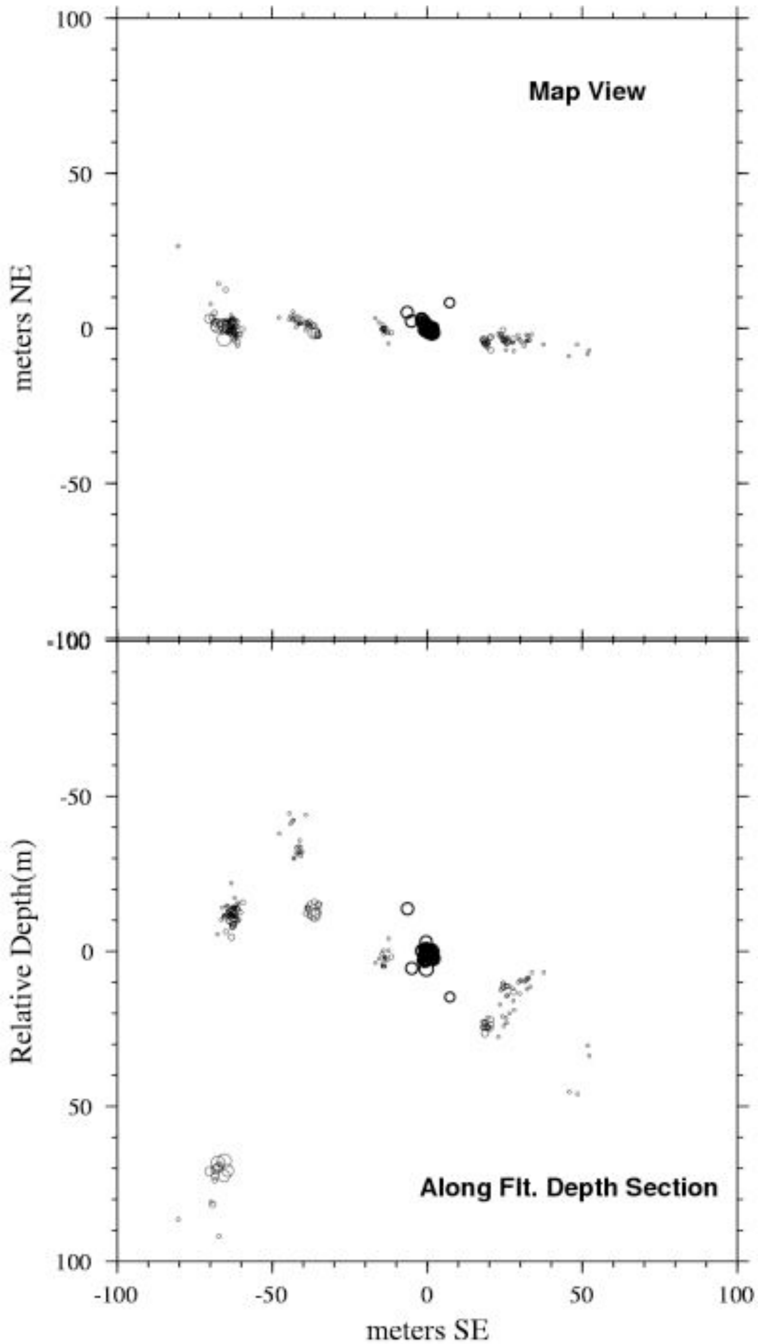

Figure 2. High-precision double-difference relative relocations of 259 similar micro-earthquakes occurring between July 27, 2001 and Sept. 1, 2008 (average of 37 events/yr.) and automatically processed using HRSN continuous seismograms and only picks and event waveforms from **one** reference event (located in map view at relative location coordinates 0,0 and at lat. 35.942814; lon. -120.503377; depth 4.326 km). Magnitudes were automatically determined for all the events and ranged from 0.0 to 1.1 Mw. Only 66 (25%) of these events were cataloged by the USGS's NCSN routine catalog and of these only 22 (8%) had magnitudes in that catalog.

Despite the automated processing, the resolution of this catalog clearly defines structures on the scale of ~10 meters, and the clustered nature of the seismicity suggests that not only is the cluster of events associated with the reference of a repeating nature, but that the other clusters are likely to be repeating in nature as well.

Illumination of the network by such clustered and similar magnitude repeating events are useful both for monitoring the state-of-health and response of the HRSN, and for a variety of research applications.

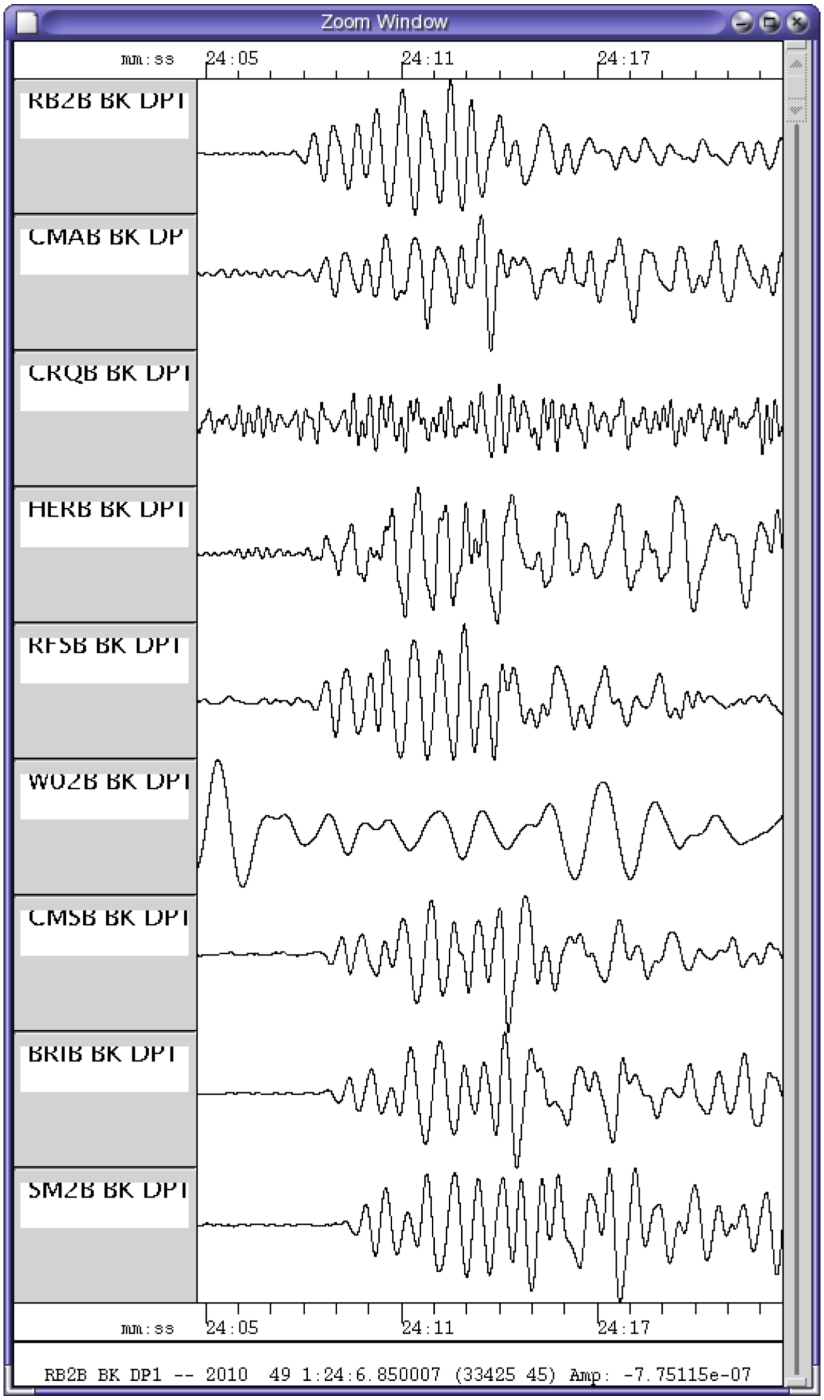

Figure 3. Vertical component (DP1) absolute ground accelerations, 0.6-3.5 Hz BP filtered, for the deep focus teleseism event: 2010/02/18 01:13:19 42.5870 sec. 6.90 Mw are shown for 9 HFN stations. The traces are in order of distance from the event. Station BRIB has the best overall performance with the cleanest P-wave signal. On the other hand, W02B is not recording ground motion. Of the remaining stations, RB2B, CMAB, and SM2B exhibit large 60 Hz signal contamination (not shown due to filtering).

All stations except CRQB and W02B recorded the P-wave signal with comparable amplitudes. CRQB is very noisy, and its P-wave signal is barely perceptable at this shallow noisey site.

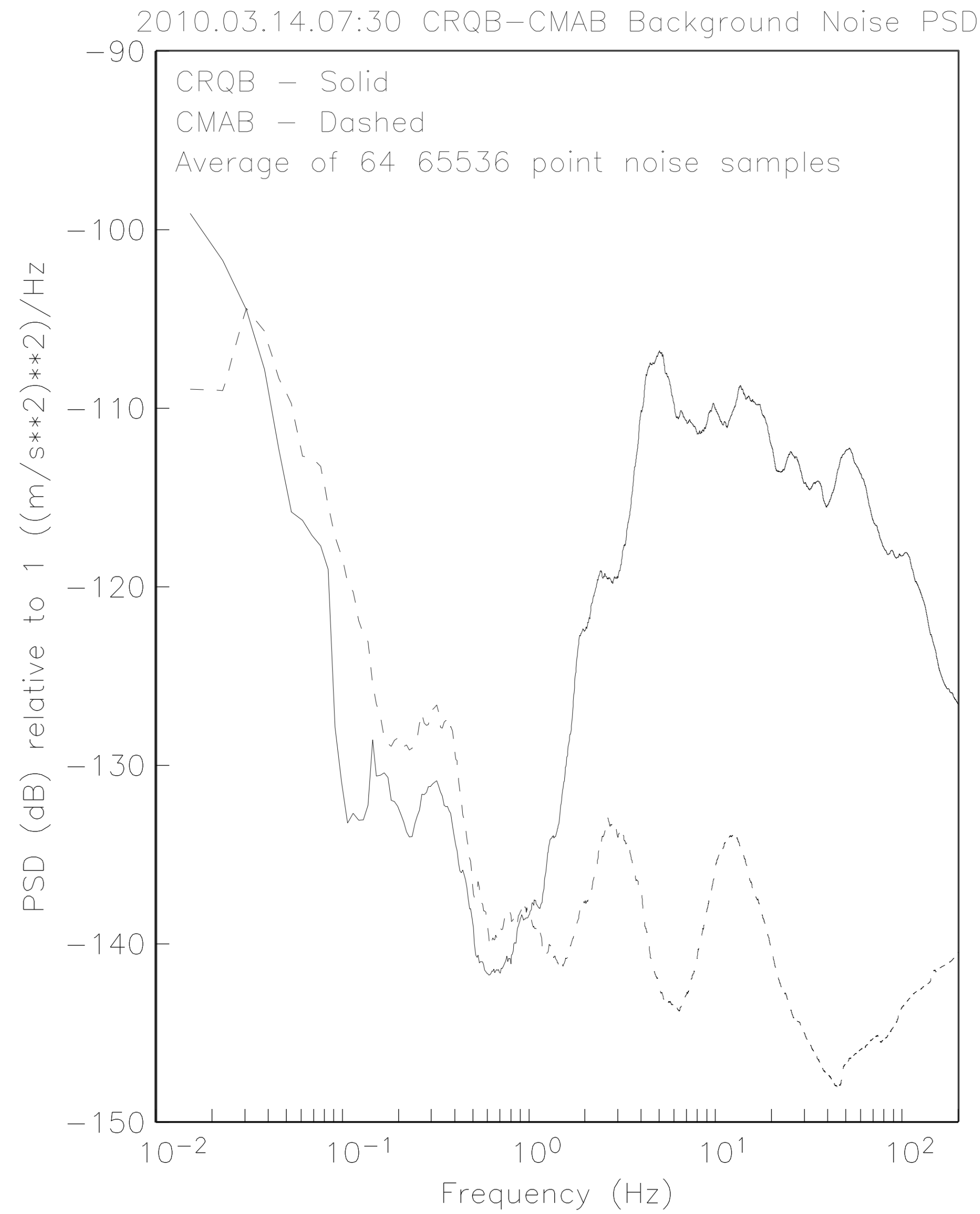

Figure 4. A quiet 1 hour window early on a Sunday morning, starting at 2010/03/14,07:30 which contained no seismic events. The average background noise PSD for this interval was determined by averaging 64 2**16 point time series in the hour window and a smoothed version of this data is shown where the smoothing is done using a boxcar filter whose logarithmic frequency width is 0.2. The observed background noise PSD level at CMAB is ~30 dB below the corresponding noise level at CRQB at frequencies above ~1.2 Hz. CMAB also has large signal contamination at 60 Hz and its harmonics (not apparent due to smoothing) which are most likely do to direct induction of the 60 Hz signal from the adjacent high-tension power lines. The CMAB PSD also has some apparent structure with peaks at ~0.3, ~0.9, ~3 and ~12 Hz which may(?) be related to modes of the new Carquinez Bridge.

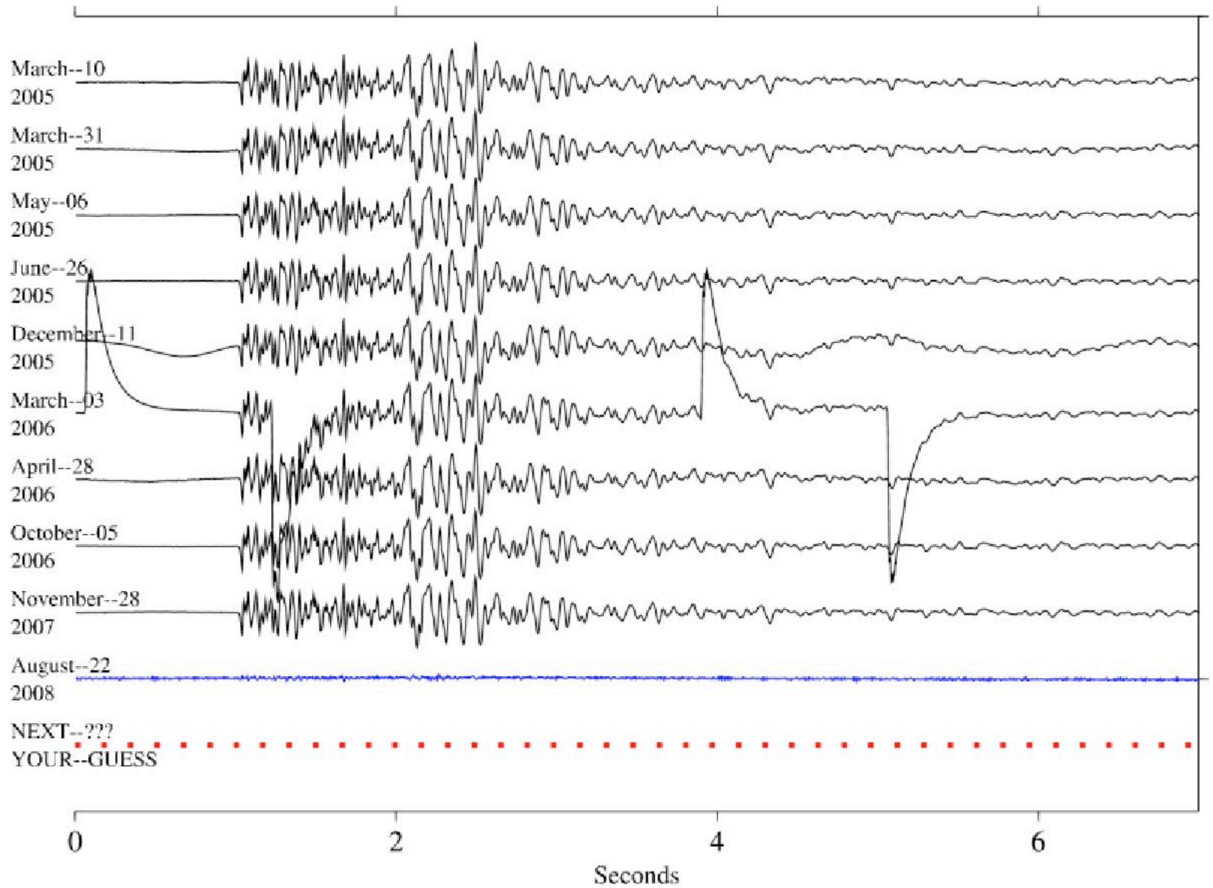

Figure 5. Ten most recent repeats of a characteristic sequence of repeating magnitude 0.9 (Mp, USGS preferred magnitude) microearthquakes recorded by vertical (DP1) channel of HRSN station MMNB. High-precision location and magnitude estimates of these events show they are extremely similar in waveform (typically 0.95 cross-correlation or better), nearly colocated (to within 5-10 m) and of essentially the same magnitude (+/- 0.13 Mp units). The dashed line labeled "NEXT" serves to illustrate that events in these types of sequences continue to repeat and that they can, therefore, be used for monitoring ongoing channel response relative to past performance. It is immediately apparent from the Figure that on March 3, 2006, the DP1 channel was experiencing significant high amplitude step-decay spiking (due to pre-amp malfunction) and that on August 22, 2008 the signal amplitude was greatly attenuated (due to excess tension and separation of the signal cable wiring). The December 11, 2005 repeat also showed low frequency wander, indicating low-battery level of the pre-amplifier component. Armed with this type of information, field engineers can quickly identify and address major problems. In addition to a visual assessment, the extreme similarity of the events lends itself to the application of differencing techniques in the time and frequency domains to automatically identify detailed SOH issues on all channels within a network.